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MANAGEMENT OF RETURN FLOWS IN TEXAS

Dan M. Wells, et al

Texas University
Austin, Texas

31 May 1966

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Management of Return Flows in Texas

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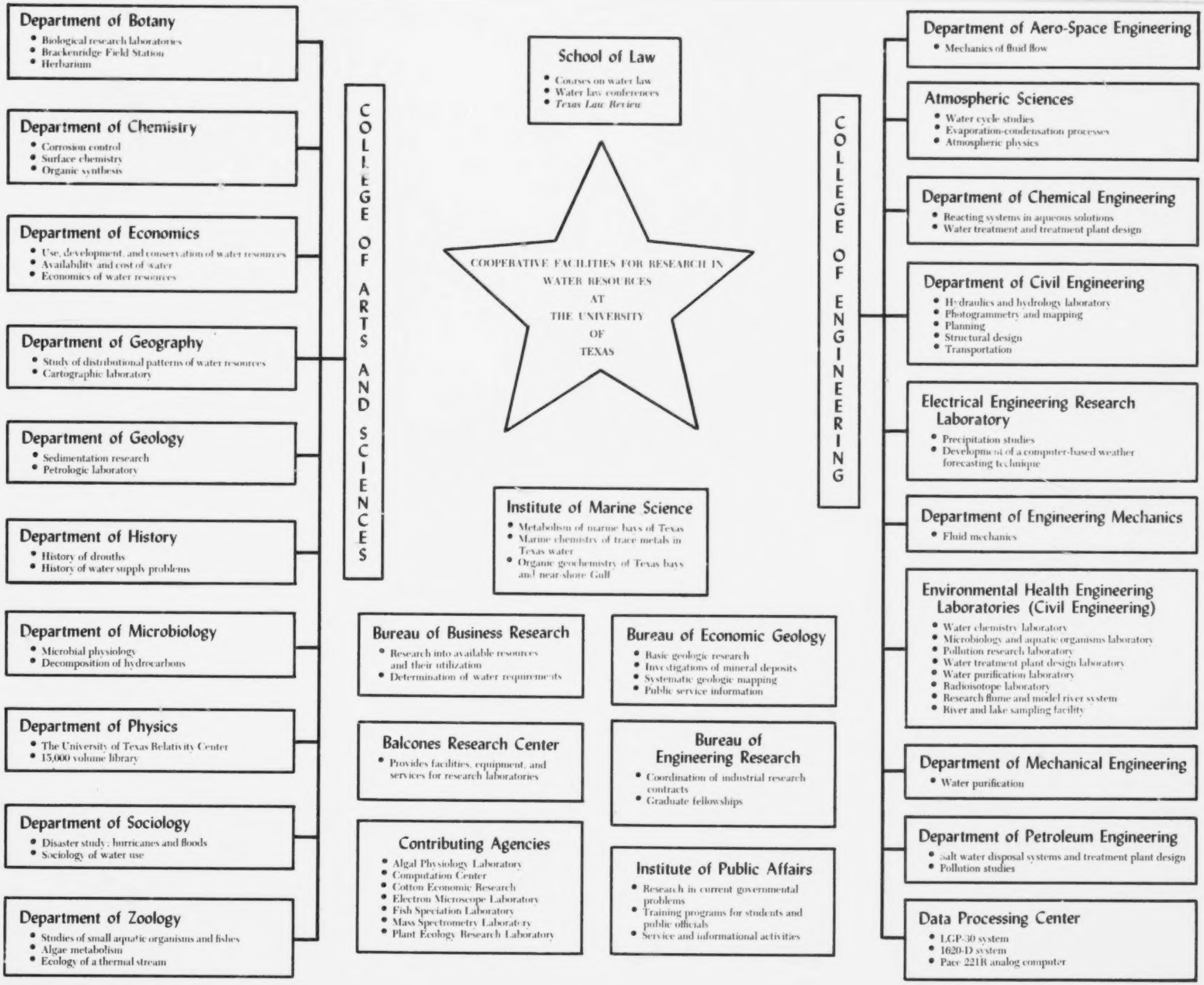

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MANAGEMENT OF RETURN FLOWS IN TEXAS

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ABSTRACT

MANAGEMENT OF RETURN FLOWS IN TEXAS

The present quantity, quality, and location of municipal and industrial return flows in Texas were estimated on the basis of available data at state regulatory agencies. Similarly, the potential impact of these return flows on the state's waterways has been evaluated. Previously developed methods for projecting water requirements and both quantity and quality of return flow were refined and used to make projections for each decade through the year 2020 for the entire state.

Trading areas and drainage basins were the basic units for the projections. A trading area includes from one to 27 counties surrounded by either a Standard Metropolitan Statistical Area or a locally important population center. A drainage basin is defined as either a river basin, an intervening coastal area between river basins, or the 10- to 15-mile wide strip of land adjacent to a bay or estuary.

The effects of projected return flows on bays and estuaries were estimated by means of simplified mixing and dissolved oxygen models. Although much of the important input data required by the models were estimated, results generally agreed with present field conditions, so far as they are known.

The applicability of optimization techniques to stream quality management was demonstrated by development of a dynamic programming model for quality control. Indications are that savings made possible by use of the model are accompanied by a substantial improvement in average stream quality.

CONCLUSIONS AND RECOMMENDATIONS

1. Projected Wastewater Quantities: The present municipal and industrial wastewater releases, respectively, are 0.8 and 1.3 million acre-feet per year. The total projected wastewater releases by the years 1980 and 2020 are expected to reach about 3 and 6 million acre-feet per year. These estimates are based on potential water requirements.

   The present municipal water use (1963 basis) and industrial use (1964 basis) involve about 1.3 and 1.9 million acre-feet per year, respectively. The total projected quantities of water for the same uses by the years 1980 and 2020 are estimated to be 5 and 12 million acre-feet per year.

2. Projected Wastewater Quality: The condition of surface waters in the future will become increasingly dependent on the quality of municipal and industrial effluents. Planned and incidental reuse of water will increase as water requirements increase, and such reuse will be made feasible only by effective effluent quality control. By the year 1970, advanced wastewater treatment will be required in some areas.

3. Projected Quality Control: Estimates provided herein indicate that localized pollution, eutrophication of entire rivers and bays, and loss of the fisheries and other water-related industries may occur unless appropriate remedial wastewater treatment or waste disposal actions are taken.

   The present treatment levels will not be adequate for treating the projected future inflows from municipal and industrial wastewater treatment plants. Considering the additional nutrients and oxygen-demanding wastes that will be produced by increased urban runoffs and agricultural return flows, one concludes that much of the state's waters will not be available for man's indirect use and personal enjoyment if the total concentrations of certain pollutants are not materially reduced in the future.

Present biological wastewater treatment plants will require upgrading to include denitrification and phosphate removal processes. Industrial processes will need to make increasing use of product recovery and process modification.

4. Projected Dilution Requirements: The dispersal of the potential organic pollutants and the solution of the nutrient problem in bays and estuaries cannot be accomplished solely by dilution with either high purity freshwaters or saline Gulf waters.

   Within the limits of available data, future dilution water requirements to maintain present quality conditions were found to increase rapidly. This increase is more rapid than potential pollutant quantity increases. It is estimated that about one million acre-feet of dilution water may be required for Galveston Bay by 1980 to maintain the present level of dissolved oxygen and about three million acre-feet per year may be required to maintain relative phosphate levels. By the year 2020 the requirements in Galveston Bay may be three million acre-feet per year for dissolved oxygen control and twelve million acre-feet per year for phosphate control.

5. Stream Quality Control: The applicability of dynamic programming methods to the optimization of treatment aimed at maintenance of stream standards was demonstrated. With the cost function used, indications are that the application of optimization techniques to the maintenance of stream standards will result in much better average stream quality at a fairly nominal reduction in total cost, particularly when a low allowable stream concentration is specified.

   It is recommended that the modest program developed in this research be expanded to include degradable pollutants, the effects of reservoirs on pollution control, low-flow augmentation, and other factors which affect stream quality.

Return flows from agricultural water use and runoff from rural and urban developments are known to contribute to the degradation of stream quality, but very little quantitative data exist. It is recommended that research be undertaken for the purpose of evaluating the contributions of these sources to stream pollution.

Finally, it is recommended that a comprehensive research program be undertaken on one of the major river systems in Texas for the purpose of evaluating some of the variables that determine the effects of return flows on such systems, and for the purpose of establishing a system of quality measurement for future quality control.

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I INTRODUCTION

Important work is being done by many investigators who are attempting to elucidate the relationships that control water and wastewater treatment processes. Others are seeking improved techniques for defining and quantifying the variables involved in determining the fate of pollutants that are introduced into streams, and still others are attempting to refine the methodology used in forecasting stream flows. The fact that these and many other separate aspects of water resources management are being investigated separately suggested the need for a broad-based study of the overall water quality management problem in Texas. Such a study could focus attention on present problems, indicate the magnitude of these problems, and perhaps cast some light on future problem areas.

For purposes of this research, a potential water quality problem exists when the return flows from municipal and industrial uses of water so degrade the quality of the receiving water as to significantly reduce its value to potential downstream users. In this context, the utilization of a receiving water's assimilative capacity for waste disposal is considered to be a legitimate and rational action.

The assimilative capacity of some receiving waters has been exceeded under present conditions (1). Unless return flow quality is steadily upgraded in the future, this condition will become more widespread.

Continued progress in the management of water resources through transbasin diversions and regulation of streamflow by the construction of dams and reservoirs will require constant upgrading of stream quality in many cases because of the tendency of such reservoirs to concentrate dissolved inorganic materials by evaporation, segregate waters by stratification, and enhance nuisances by eutrophication. In some cases these effects are offset by increased detention time in reservoirs, and by the beneficial effects of low-flow augmentation.

It seems to be evident that increasing economic resources will be devoted to the water resources management field in the future. Optimum allocation of these resources will depend upon a knowledge of the nature of obstacles to be overcome, and the sequence in which they will be encountered.

Objectives

The primary objectives of this research were (a) to delineate and to localize present and projected municipal and industrial return flows in Texas, (b) to quantify some of the constituents of these return flows, (c) to identify some of the problems that may result from projected return flows, (d) to point out some of the shortcomings in present water-quality data collection practices, and (e) to develop a generally applicable computational method of minimizing the treatment cost for maintaining a predetermined stream quality.

Scope

Data related to the use, consumption, and quality of water were obtained from the Texas State Department of Health, the Texas Water Pollution Control Board, the Texas Water Development Board, the Bureau of Business Research of The University of Texas, and the literature. Detailed analyses of these data were made utilizing the CDC 1604 computer at The University of Texas. Results were obtained for all cities with a population in excess of 5000, for all counties, and for all Standard Metropolitan Statistical Areas as defined by the Bureau of the Census of the United States Department of Commerce. These results were then grouped into the trading areas and drainage basins for which results are shown in subsequent sections.

Some duplication of effort is involved in obtaining results based on both trading areas and drainage basins, but both concepts are necessary to an adequate evaluation of the water resources problem. Trading areas are the more logical units on which to project water requirements because water will be required where people and industry congregate, regardless of topographic features of the area. Drainage basins are more logical units on which to project return flows, because natural watercourses are usually the ultimate waste conveyance systems for areas which they drain. Hence, the interdependency of water use and return flow makes it desirable to relate both water use and return flow to both trading areas and drainage basins.

Limitations

Many inadequacies of data were encountered, but field checking of questionable data was beyond the scope of this research. In cases of conflict between two or more sources of data, judgment was used in selecting the more reasonable value. Such inadequacies serve to emphasize the need for more comprehensive and reliable means of gathering quality data.

Bays and estuaries that receive substantial quantities of freshwater inflow are vastly more complex systems than are streams, in both physical and biological senses. For example, transport by a flowing stream occurs only in a downstream direction, with primary currents caused by gravitational forces. Transport in a bay or estuary may occur in any direction as a result of currents from tidal action, wind action, density gradients, freshwater inflows, and other factors. The direction is not constant with time as is the case in a stream.

It is therefore a simple matter to infer that the introduction of biologically degradable organic wastes to a bay or estuary will depress the dissolved oxygen concentration in the receiving water, but it is not possible to predict with a high level of confidence either the magnitude or the areal extent of the depression that will result from the introduction of a particular quantity of such wastes. The basic data relative to transport, mixing, reaeration, deoxygenation, effects of bottom deposits, and many other factors are not available to the extent and with the degree of accuracy necessary for such a prediction.

Regardless of these inadequacies of available data, a computational model based on many simplifications was developed in order to obtain estimates of the general effect of projected return flows. As more nearly complete and more useful data become available in the future, it should be possible to refine the model so that estimates obtained will be more indicative of actual results.

II QUANTITY, QUALITY, AND LOCATION OF PRESENT AND PROJECTED RETURN FLOWS

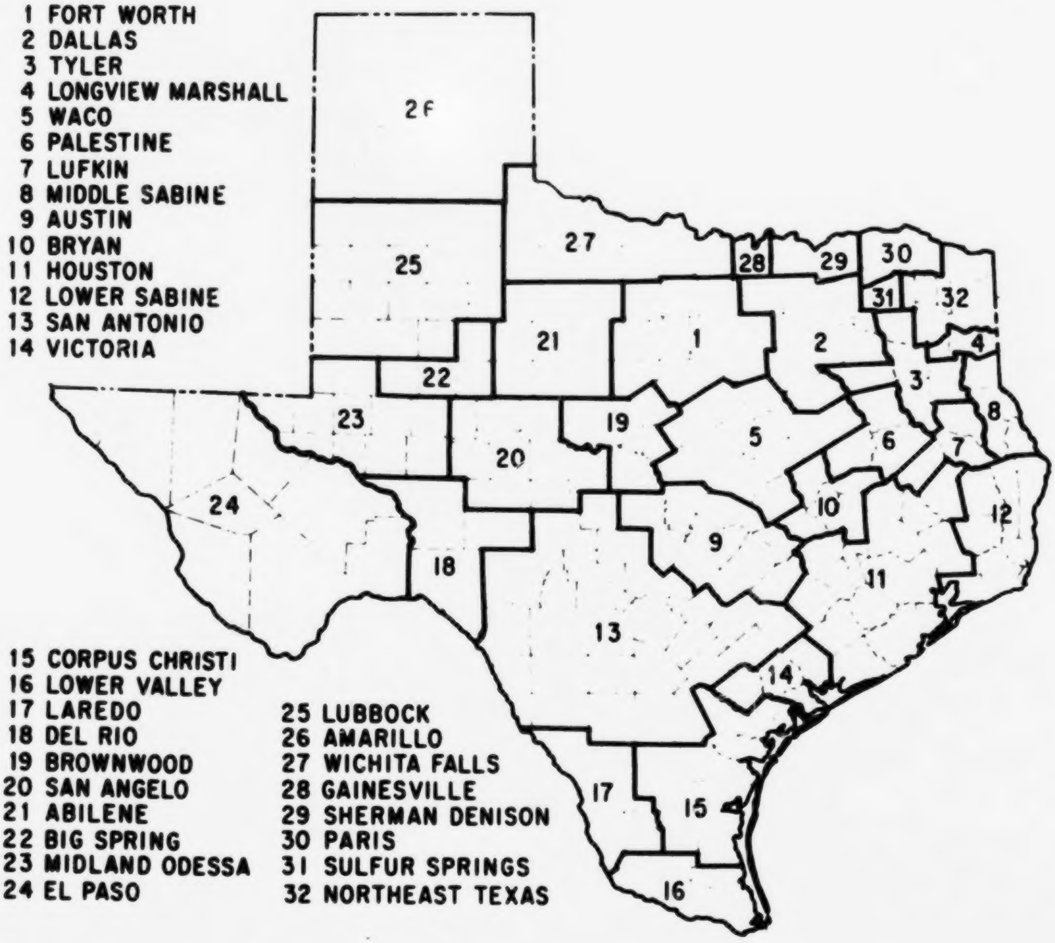
Future return flow may be an important factor in determining the value and usefulness of the total water resource in Texas. This used water represents a large potential source of usable supply only if it is properly managed. If return flow is mismanaged, it may seriously damage the quality of available surface and ground waters throughout most areas of the state. Factual data on which to base decisions are essential to the development of rational management policies. Effective management of the total water resources of the state therefore requires a knowledge of the quantity and quality of all potential water supplies, including return flows.

The research discussed in this section was undertaken for the purpose of quantifying, qualifying, and localizing present municipal and industrial return flows throughout the state, and projecting these data to the year 2020. Most of the results obtained in this research have been included in detail in a report to the Texas Water Development Board by the Center for Research in Water Resources. (2)

Organization of the Research

The research discussed in this section is based on a fundamental concept which assumes that the quantity of return flow in a limited geographic area is related in a rational and determinable manner to the quantity of water used in that area. This concept was used in a study of water reuse made in 1957, (3) and the validity of the concept was confirmed by the research reported herein. Historical records of water use and return flow were used in evaluating the relationship of return flow to water use (S/W ratio), and projections of return flow were made by applying the relationship to water use projections made jointly by the Bureau of Business Research of The University of Texas and The Texas Water Development Board.

Present and projected municipal and industrial water requirements were developed for all urban areas with a population of 5000 or more, for all Standard Metropolitan Statistical Areas (SMSA) as defined by the U. S. Department of Commerce, and for all counties that are not included in any of the 21 Standard Metropolitan Statistical Areas in the state. Water requirements that were developed for the above areas were grouped into 32 trading areas as defined by The Bureau of Business Research of The University of Texas, Fig. 2-1. Projected return flows were developed in the same detail as were water requirements, but results for units smaller than trading areas have not been included in this section.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13 SAN ANTONIO
14 VICTORIA
15 CORPUS CHRISTI
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17 LAREDO
18 DEL RIO
19 BROWNWOOD
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FIG.2-1.LOCATION OF TRADING AREAS IN TEXAS

Qualitative projections of return flow were made for three different assumptions regarding future effluent quality. Results obtained for these three conditions should be useful in the future establishment of water quality criteria.

Evaluation of Municipal Return Flows

All computations of municipal S/W ratios were based on water use and return flow data provided by the Texas State Department of Health (TSDH). Water use data available from this source consist of routine reports filed by operators of public water supply systems and summary reports published periodically by the TSDH (4). Return flow data included routine reports filed by plant operators, and published and unpublished data based on inventories of municipal waste treatment plants as made by the TSDH (5, 6).

Present qualities of municipal return flows were synthesized from data obtained from the literature, the TSDH, and the Texas Water Pollution Control Board (7, 8, 9, 10).

Municipal Sewage-to-Water (S/W) Ratios

The relationship of return flow to water use is influenced by the total population, population density, water uses, climatic variation, economic conditions, water costs, water quality, and many other factors. The relationship varies widely from year to year for any particular city, but annual precipitation appears to be the most important single factor in determining what the relationship will be. The influence of annual precipitation on the S/W ratio can be expressed in an equation of the form: $Y = a + bX$, in which Y is the S/W ratio, a and b are constants, and X is the annual precipitation in inches.

Equations of this type were derived for each major city for which adequate historical records are available, and the S/W ratios for normal annual precipitation were determined. Return flow projections were then made on the basis of projected water requirements and normal S/W ratios.

Where adequate historical records were not available, S/W ratios were based on such records as were available and on the calculated ratios for cities in similar climatic areas.

Present municipal S/W ratios, adjusted for average precipitation, decrease in a westerly direction from a high of 0.86 in the Lower Sabine Trading Area to a low of 0.31 in the El Paso Trading Area. Most of the S/W ratios fall within the range of 0.45 to 0.75 and the weighted mean of all values is 0.60.

Projected S/W ratios have generally been reduced slightly each decade to account for the fact that the S/W ratio for a city normally declines as the population increases. The weighted mean of all values projected to the year 2020 is about 0.55. Present and projected municipal S/W ratios for each trading area for each decade are presented in Table 2-1.

Quality of Municipal Return Flows

The quality of municipal return flow, summarized by trading area in Table 2-2, is determined by two primary factors--the concentration of dissolved solids in the tap water from which the return flow is derived and the concentration of pollutants added through one cycle of municipal use. Concentrations of 5-day BOD and of suspended solids in municipal effluents are routinely evaluated by the Texas State Department of Health as an integral part of the inventory of municipal waste treatment plants referred to earlier. BOD and suspended solids concentrations data were therefore obtained directly from this source.

The concentrations of dissolved solids in tap water, which greatly affect the quality of return flow, were evaluated in a less direct manner and were found to vary widely among different areas of the state. For the entire state, the weighted average concentrations of total solids, chlorides,

Table 2-1. Municipal S/W Ratios

Trading Area	Year						
	1960	1970	1980	1990	2000	2010	2020
Fort Worth	.72	.70	.69	.67	.65	.64	.62
Dallas	.70	.67	.64	.61	.57	.54	.51
Tyler	.72	.69	.66	.63	.61	.58	.55
Longview-Marshall	.70	.70	.70	.70	.70	.70	.70
Waco	.65	.64	.63	.63	.62	.61	.60
Palestine	.65	.65	.65	.65	.65	.65	.65
Lufkin	.55	.53	.51	.49	.47	.45	.43
Middle Sabine	.75	.75	.75	.75	.75	.75	.75
Austin	.51	.49	.46	.44	.42	.39	.37
Bryan	.49	.49	.48	.48	.48	.47	.47
Houston	.68	.67	.66	.65	.64	.63	.62
Lower Sabine	.86	.85	.85	.84	.83	.83	.82
San Antonio	.73	.71	.68	.66	.64	.61	.59
Victoria	.50	.48	.47	.45	.43	.42	.40
Corpus Christi	.44	.43	.41	.40	.38	.37	.35
Lower Valley	.37	.37	.37	.36	.36	.36	.36
Laredo	.45	.44	.43	.43	.42	.41	.40
Del Rio	.35	.34	.33	.33	.32	.31	.30
Brownwood	.45	.45	.44	.44	.44	.43	.43
San Angelo	.45	.44	.43	.43	.42	.41	.40
Abilene	.53	.52	.50	.49	.48	.46	.45
Big Spring	.46	.45	.44	.43	.42	.41	.40
Midland-Odessa	.46	.45	.44	.43	.42	.41	.40
El Paso	.31	.31	.31	.31	.30	.30	.30
Lubbock	.53	.51	.50	.48	.46	.45	.43
Amarillo	.46	.45	.44	.43	.42	.41	.40
Wichita Falls	.43	.43	.42	.42	.41	.41	.40
Gainesville	.65	.64	.63	.63	.62	.61	.60
Sherman-Denison	.65	.64	.63	.63	.62	.61	.60
Paris	.64	.63	.63	.62	.61	.61	.60
Sulfur Springs	.80	.78	.77	.75	.73	.72	.70
Northeast Texas	.75	.74	.73	.73	.72	.71	.70

Table 2-2. Summary of Quality of Municipal Return Flow (1964)

Trading Area	Concentration of Pollutants (mg/l)					
	BOD	Susp. Solids	Total Solids	Cl^-	NO_3	PO_4
Fort Worth	27	32	488	102	22	24
Dallas	32	40	602	127	22	24
Tyler	30	37	409	93	22	24
Longview-Marshall	6	26	347	104	23	24
Waco	40	38	642	138	24	24
Palestine	69	63	560	116	22	24
Lufkin	43	61	526	97	22	24
Middle Sabine	27	46	508	96	23	24
Austin	17	29	915	144	26	24
Bryan	25	52	515	110	22	24
Houston	26	42	674	171	22	24
Lower Sabine	12	22	421	122	22	24
San Antonio	21	19	555	108	27	24
Victoria	18	25	694	248	22	24
Corpus Christi	17	49	785	251	23	24
Lower Valley	32	72	1019	258	23	24
Laredo	94	50	785	117	27	24
Del Rio	2	5	494	89	30	24
Brownwood	34	36	422	110	23	24
San Angelo	50	42	639	180	23	24
Abilene	24	34	510	116	23	24
Big Spring	59	36	517	106	22	24
Midland-Odessa	22	51	957	196	31	24
El Paso	44	37	682	160	23	24
Lubbock	95	103	844	152	30	24
Amarillo	70	62	603	100	27	24
Wichita Falls	50	74	499	111	30	24
Gainesville	41	41	633	100	23	24
Sherman-Denison	38	48	872	206	23	24
Paris	47	17	471	105	22	24
Sulfur Springs	22	30	288	81	22	24
Northeast Texas	53	35	466	116	23	24
State Total	32	40	646	146	24	24

and nitrates in tap water were found to be 424, 71, and 3 mg/l, respectively.

Concentrations of dissolved solids in tap water, Table 2-3, were obtained from a report on the chemical analyses of water supplied by public water systems throughout the state (9). Since many cities have more than one source of supply, the report may list data for more than one set of analyses for a city. It was therefore necessary to study the listings and determine, partly on the basis of judgment, the most reasonable concentrations of dissolved solids in the tap water of each city. Average values of pollutant buildup through one cycle of municipal use were added to these tap water concentrations in order to find the return flow concentrations of dissolved solids.

On the average, one cycle of municipal use adds 222 mg/l of total solids, 75 mg/l of chlorides, 22 mg/l of nitrates, and 24 mg/l of phosphates to the tap water concentrations (7,8,11). It was assumed that these average values were valid for all areas of the state, although it is recognized that the values may vary from city to city. The concentrations of total solids, chlorides, nitrates, and phosphates shown in Table 2-2 therefore represent the tap water concentrations plus the average buildup for one cycle of municipal use.

Concentrations of phosphates and nitrates, evaluated as described above, were practically uniform at 24 mg/l throughout the state; but 5-day BOD, suspended solids, total solids, and chlorides were found to have relatively wide ranges of values. The weighted average concentration of reported 5-day BOD in the state was calculated to be 32 mg/l, ranging from a high of 95 mg/l in the Lubbock Trading Area to a low of 2 mg/l reported in the Del Rio Trading Area. The low value is probably not realistic but rather indicative of data reporting techniques.

Total solids concentrations were found to vary from 1019 mg/l in the Lower Valley to 288 mg/l in the Sulphur Springs Trading Area, with the

Table 2-3. Summary of Quality of Municipal Tap Water

Trading Area	Concentration of Pollutants (mg/l)		
	Total Solids	Cl^-	NO_3
Fort Worth	266	27	0
Dallas	380	52	0
Tyler	187	18	0
Longview-Marshall	125	29	1
Waco	420	63	2
Palestine	338	41	0
Lufkin	304	22	0
Middle Sabine	286	21	1
Austin	693	69	4
Bryan	293	35	0
Houston	452	96	0
Lower Sabine	199	47	0
San Antonio	333	33	5
Victoria	472	173	0
Corpus Christi	563	176	1
Lower Valley	797	183	1
Laredo	563	102	5
Del Rio	272	14	8
Brownwood	200	35	1
San Angelo	417	105	1
Abilene	288	41	1
Big Spring	295	31	0
Midland-Odessa	735	121	9
El Paso	460	85	1
Lubbock	622	77	8
Amarillo	381	25	5
Wichita Falls	277	36	8
Gainesville	411	25	1
Sherman-Denison	650	131	1
Paris	249	30	0
Sulfur Springs	66	6	0
Northeast Texas	244	41	1
State Average	424	71	2

average for Texas being 646 mg/l. Variations in the concentrations of suspended solids and chlorides were determined to parallel the variations in BOD and total solids, respectively.

Water quality in Texas tends to improve in an easterly direction, with the best quality water occurring in the Sulphur Springs Trading Area, as indicated above.

Evaluation of Industrial Return Flows

All computations of industrial S/W ratios were based on water use and return flow data obtained from a survey of industrial water users which was made by the Texas Water Commission in the spring of 1965. For this survey, questionnaires were mailed to approximately 3500 industrial firms throughout the state. More than 90 percent of the industries responded to the questionnaire, and approximately 1200 replies contained usable information. It is believed that over 95 percent of the actual water use was covered in the usable replies.

Present quality data for industrial return flow were obtained by analysis of waste discharge permits issued by the Texas Water Pollution Control Board.

Industrial Return Flow to Water Use (S/W) Ratios

Industrial S/W ratios were found to vary widely for different areas of the state and, while they tend to be somewhat lower in the more arid portions of the state, they also vary greatly among different types of industries, regardless of location.

Industrial S/W ratios vary over a wider range of values than do municipal S/W ratios. The Victoria Trading Area reported the highest ratio, 0.95, while the lowest ratio, 0.11, was reported in the Laredo Trading Area. The overall average for the state was found to be 0.88, but this ratio included large quantities of saline water. When saline water was excluded from calculations, the state average ratio was 0.69.

Saline water accounts for about 64 percent of the total industrial water intake, with the chemical industry using about 79 percent of the total saline water intake. Petroleum refining and miscellaneous minor industries together use another 20 percent of the saline water intake, leaving about 1 percent for all other industries.

The major water-using industries tend to use about four times as much water for cooling purposes as for process water. Because of reuse of cooling water, the quantity used for cooling was more than the total intake for all industrial classes except the textile, paper, stone, clay, and glass industries. All industrial classes except the paper industry reported that the quantity of water recirculated within the plant exceeded the total intake. For the entire state, recirculated water volume was about four times the total intake, including saline water, indicating that intake water is put through five cycles of use before being discharged, Tables 2-4 and 2-5. Industrial water use and return flow by Trading Area are tabulated in Table 2-6.

Industrial S/W ratios are highly dependent on the number of times water is recycled within the plant before being discharged. Each use cycle consumes about 1.8 percent of the intake water as shown in Fig. 2-2.

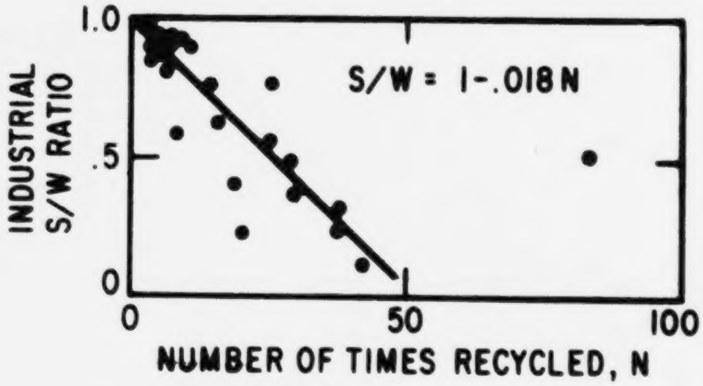

FIG. 2-2. EFFECT OF RECYCLING ON INDUSTRIAL S/W RATIO

Table 2-4. Summary of Industrial Water Use in 1964 by Industrial Classification (MGY)

Industrial Class	Quantity and Source of Intake					
	Total	Fresh	Munic Sewage	Other Contam.	Saline	Present Need
Mining	20716	17514	0	3212	44	41
Primary Metals	20438	6786	0	3365	10427	15
Transportation	12967	1991	0	10975	0	0
Stone, Clay, Glass	14112	11872	6	1032	1202	51
Food Production	13442	13147	5	279	7	422
Textiles	1119	1119	0	0	0	0
Paper & Products	29208	24516	0	2	4690	8663
Chemicals	1185501	68051	1426	196948	916090	657
Petroleum Refining	196930	62771	487	30472	103124	53
Miscellaneous	309436	47188	912	131883	129452	321
Total	1802870	254957	2836	378171	1165036	10221

Table 2-5. Summary of Industrial Return Flow and Usage of Water in 1964 by Industrial Classification (MGY)

Industrial Class	Quantity of Water					
	Reused	Return Flow	Process Usage	Cooling Usage	Boiler Feed	S/W Percent
Mining	1557141	5195	384532	1088983	11451	25
Primary Metals	76887	15194	15382	79132	3280	74
Transportation	24789	12188	16880	16974	796	94
Stone, Clay, Glass	45457	9955	13406	6882	543	71
Food Production	28605	10604	14183	22469	4822	79
Textiles	2571	968	3432	39	219	87
Paper & Products	21322	28213	28353	18134	10671	97
Chemicals	1469718	1119653	557468	2055914	29018	95
Petroleum Refining	2309496	149824	592926	1877868	43802	76
Miscellaneous	1611745	235362	7103	1901098	5912	76
Total	7147731	1587157	1633664	7067492	110513	88

Table 2-6. Summary of Industrial Water Use and Return Flow in 1964 (MGY)

Trading Area	Quantity of Water							
	Total Water	Fresh Water	Mun Sew	Other Contam	Saline Water	Reused Water	Return Flow	S/W Pct
Fort Worth	17713	6185	0	11209	303	322350	13501	76
Dallas	17849	17771	0	78	0	303298	4982	28
Tyler	3593	3532	0	35	0	103065	948	26
Longview-Marshall	6247	1412	0	4835	0	162912	2047	33
Waco	7840	4681	0	3159	0	172017	1632	21
Palestine	205	195	0	0	0	1506	137	67
Lufkin	546	458	0	16	72	2307	429	79
Middle Sabine	896	820	0	76	0	22527	404	45
Austin	1872	1733	1	138	0	1956	1593	85
Bryan	46	46	0	0	0	930	18	39
Houston	1039751	91785	5	138246	807851	2389383	955259	92
Lower Sabine	487312	44683	4	155179	287445	1281561	434338	89
San Antonio	15265	9747	0	5523	0	41697	5833	38
Victoria	76271	18237	0	57105	929	146056	72808	95
Corpus Christi	34071	9362	0	301	24254	363662	27062	80
Lower Valley	45591	1028	0	573	43990	42735	45125	99
Laredo	103	86	0	17	0	4076	12	11
Del Rio	467	467	0	0	0	2227	150	32
Brownwood	33	33	0	0	0	50	33	100
San Angelo	402	395	0	0	7	8524	205	51
Abilene	341	301	0	22	18	40981	190	56
Big Spring	1794	1489	186	119	0	162965	437	24
Midland-Odessa	6472	4619	1242	551	60	717408	2257	35
El Paso	4439	4333	0	100	6	113946	1695	38
Lubbock	4160	4018	0	142	0	57590	1474	35
Amarillo	19386	18033	1399	26	0	398467	9452	49
Wichita Falls	398	185	0	186	0	7639	200	50
Gainesville	68	68	0	0	0	95	36	53
Sherman-Denison	3037	2734	0	303	0	162409	674	22
Paris	850	850	0	0	0	40320	191	23
Sulfur Springs	76	67	0	9	0	612	55	72
Northeast Texas	5833	5612	0	221	0	70463	3983	68

This study is concerned with potentially reusable return flows, so the industrial S/W ratios obtained from the survey were modified to exclude saline water from the calculations. The modification was based on the assumptions that saline water would be used on a once through basis only and that this single use cycle would consume about 1.8 percent of the saline intake. Thus, saline intake was subtracted from total intake, and waste was reduced by 98.2 percent of saline intake to compute the non-saline S/W ratio for each Trading Area. Results obtained from this modification indicate that non-saline water is recycled an average of about eleven times before being discharged.

Projections of S/W ratios were based on the assumption that increasingly efficient use of water will reduce all ratios to 75 percent of their present values by the year 2020, unless the ratio is now less than 0.25, in which case the S/W ratio was assumed to remain constant. Present and projected industrial S/W ratios are listed by decade for each Trading Area in Table 2-7.

Quality of Industrial Return Flows

The quality of industrial return flow was found to be much less uniform and generally much lower than the quality of municipal return flow. Average concentrations of pollutants in the total return flow for the state are about five times as great for industrial return flows as for municipal return flows, as shown in Table 2-8 (12). As noted in this table, many industries and municipalities, as represented by return flows, do not presently report concentrations of contaminants in commonly accepted terms. For example, it is noted that COD concentration is reported for less than 1 percent of municipal return flows.

Waste discharge permits, upon which the quality of industrial return flow was based, were unchecked and unverified by the Water Pollution Control Board, were incomplete in most cases, and are believed to

Table 2-7. Industrial S/W Ratios

Trading Area	Year						
	1960	1970	1980	1990	2000	2010	2020
Fort Worth	.76	.72	.69	.66	.63	.60	.57
Dallas	.28	.27	.25	.24	.23	.22	.21
Tyler	.26	.25	.24	.23	.21	.20	.19
Longview-Marshall	.33	.31	.30	.29	.27	.26	.25
Waco	.21	.21	.21	.21	.21	.21	.21
Palestine	.67	.64	.61	.58	.55	.53	.50
Lufkin	.79	.75	.72	.68	.65	.62	.59
Middle Sabine	.45	.43	.41	.39	.37	.35	.34
Austin	.85	.81	.77	.74	.70	.67	.64
Bryan	.39	.37	.35	.34	.32	.31	.29
Houston	.66	.63	.60	.57	.54	.52	.49
Lower Sabine	.76	.72	.69	.66	.63	.60	.57
San Antonio	.38	.36	.35	.33	.31	.30	.28
Victoria	.95	.91	.86	.82	.78	.75	.71
Corpus Christi	.33	.31	.30	.29	.27	.26	.25
Lower Valley	.80	.76	.73	.69	.66	.63	.60
Laredo	.11	.11	.11	.11	.11	.11	.11
Del Rio	.32	.30	.29	.28	.26	.25	.24
Brownwood	.99	.94	.90	.86	.82	.78	.74
San Angelo	.51	.49	.46	.44	.42	.40	.38
Abilene	.56	.53	.51	.48	.46	.44	.42
Big Spring	.24	.24	.24	.24	.24	.24	.24
Midland-Odessa	.35	.33	.32	.30	.29	.28	.26
El Paso	.38	.36	.35	.33	.31	.30	.28
Lubbock	.35	.33	.32	.30	.29	.28	.26
Amarillo	.49	.47	.45	.42	.40	.39	.37
Wichita Falls	.50	.48	.45	.43	.41	.39	.37
Gainesville	.53	.51	.48	.46	.44	.42	.40
Sherman-Denison	.22	.22	.22	.22	.22	.22	.22
Paris	.23	.23	.23	.23	.23	.23	.23
Sulfur Springs	.72	.69	.65	.62	.59	.57	.54
Northeast Texas	.68	.65	.62	.59	.56	.53	.51

contain generous safety factors to allow for future expansion in other cases, but they are the only available source of information. Concentrations shown in Table 2-8 should therefore be considered as indicating the order of magnitude rather than the absolute values of pollutant concentrations.

Table 2-8. State Summary - Quantity and Quality of Municipal and Industrial Return Flow, Based on Waste Discharge Permits

	Municipal	Industrial	Total
Quantity (MGY)	201269	1301671	1502940
Quality			
BOD			
Avg. Reporting (mg/l)	34	170	148
Not Reporting (%)	5	31	28
Suspended Solids			
Avg. Reporting (mg/l)	59	360	301
Not Reporting (%)	20	50	46
Total Solids			
Avg. Reporting (mg/l)	1221	6418	4920
Not Reporting (%)	69	88	85
Chlorides			
Avg. Reporting (mg/l)	177	6713	6207
Not Reporting (%)	72	49	52
COD			
Avg. Reporting (mg/l)	Neg.	815	815
Not Reporting (%)	100	54	60
Sulfates			
Avg. Reporting (mg/l)	123	657	441
Not Reporting (%)	79	95	93

Evaluation of industrial return flow quality is difficult because of its variability with time, type of manufacturing process, type of product, production volume, operating techniques, conservation practices, cost of water, quality of water, and many other factors.

Projection of Municipal and Industrial Water Requirements

Projections of municipal and industrial water requirements were made by the Bureau of Business Research of The University of Texas and the Texas Water Development Board.

The method employed in making the projections is widely used for making long-range projections. In essence, this method consists of evaluating the resources available in a limited geographic area, determining the employment in basic industries that these resources will support, calculating the service industry employment that will be generated by the basic industries, and, from the total employment, estimating the total population. Municipal (domestic) water requirements are then projected on the basis of population projections, and future industrial water requirements are estimated on the basis of the total predicted industrial development.

In general, projections are indicators of potential trends. Long-range predictions for small geographic areas are likely to be grossly inaccurate because the growth of a small area is a function of economics rather than biology. Projections for larger areas, such as the entire state or one of the larger trading areas can be expected to deviate less because the future population expansion and water use may be more clearly defined.

For convenience of reference, future municipal and industrial water requirements estimated by the Bureau of Business Research of The University of Texas and the Texas Water Development Board are presented in summary form in Table 2-9 and in detail in Appendix A.

Table 2-9. State Summary of Present and Projected Annual Municipal and Industrial Water Requirements

Year	Municipal		Industrial		Total	
	Bil Gal	1000 Ac Ft	Bil Gal	1000 Ac Ft	Bil Gal	1000 Ac Ft
1960	409	1255	430	1320	839	2575
1970	588	1804	675	2071	1263	3875
1980	787	2415	948	2909	1735	5324
1990	974	2989	1142	3505	2117	6494
2000	1209	3710	1381	4238	2591	7948
2010	1505	4618	1677	5146	3183	9764
2020	1879	5766	2044	6272	3923	12039

Projection of Municipal and Industrial Return Flows

Projected return flows are the products of estimated future water requirements and the appropriate S/W ratios. Return flows from industrial water users are slightly greater than those from municipal users at the present, and they are expected to increase at the same rate as municipal return flow through the year 2020. Approximately one-third of the total return flow will be produced in the Houston Trading Area throughout the period covered. The municipal return flow from the Houston Trading Area will increase slightly faster than will industrial return flow.

The Houston and Lower Sabine Trading Areas together will account for about 78 percent of the total industrial return flow by the year 2020, and the Houston and Dallas Trading Areas together will account for about 42 percent of the total municipal return flow, as they now do.

In general, most areas except the Lower Valley will tend to maintain their present rank as producers of return flow throughout the period covered by the study. These data are given in Table 2-10 and Appendix B.

Table 2-10. State Summary of Present and Projected Annual Municipal and Industrial Return Flows

Year	Municipal		Industrial		Total	
	Bil Gal	1000 Ac Ft	Bil Gal	1000 Ac Ft	Bil Gal	1000 Ac Ft
1960	248	761	260	798	508	1559
1970	350	1074	399	1224	749	2299
1980	459	1409	543	1666	1002	3075
1990	554	1700	629	1930	1183	3630
2000	671	2059	731	2243	1402	4302
2010	815	2501	853	2618	1668	5119
2020	991	3041	999	3066	1990	6107

Municipal, industrial, and total water requirements and return flows for the entire state are presented in graphical form in Fig. 2-3. Statewide figures are of little practical value because the potential for use or reuse of water depends on the location of water with respect to the need for it.

Projection of Quality of Return Flows

Future effluent or stream standards which will determine return flow quality are not known. For this reason, projections based on three different possible standards have been made. The first projection is based on the assumption that present stream quality will be maintained; the second assumes that present effluent quality will be maintained; and the third assumes that the concentrations of suspended solids and 5-day BOD will be reduced to 20 mg/l. These three possible standards are likely to bracket the range of standards considered by regulatory authorities and should provide a reasonable basis for long range planning as related to all phases of water resource management.

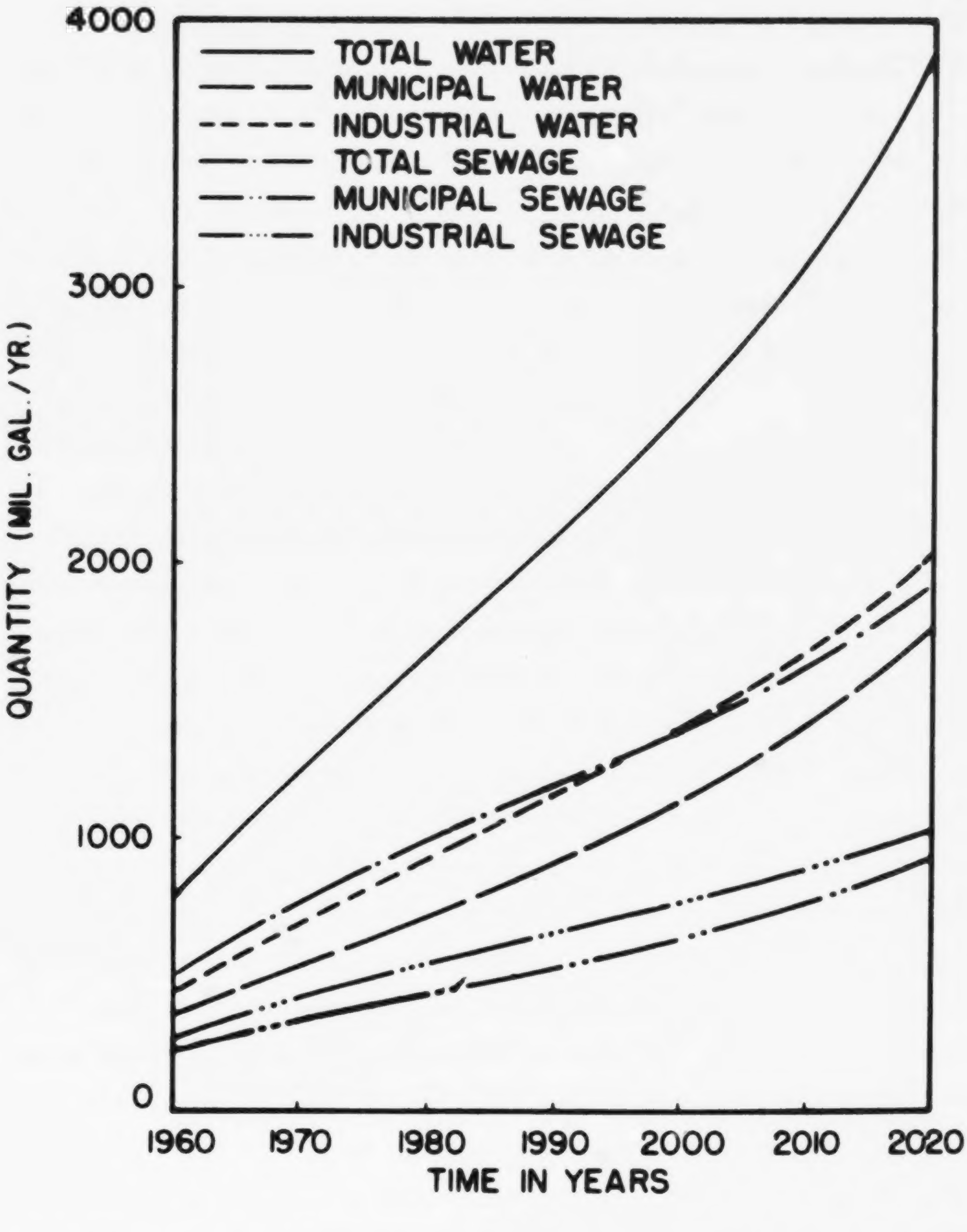

FIG. 2-3. SUMMARY OF PRESENT AND PROJECTED WATER USE AND RETURN FLOW IN TEXAS.

Maintaining Present Stream Quality

On an average basis the present organic quality of Texas streams can be maintained by conventional secondary biological treatment of all wastes until about 1975, although more advanced treatment processes will be required in some areas before 1970. Areas which should be likely candidates for nutrient removal are municipalities in the Ft. Worth, Dallas, Houston, and San Antonio Trading Areas. Agriculture is also a significant contributor of nutrients but indications are that the agricultural contribution is considerably less than the municipal contribution (11). Similarly, surface runoff from urban and rural developments may add a highly significant waste load to the receiving waters (13).

In areas such as Ft. Worth, Dallas, San Antonio, and possibly Houston, it appears that 5-day BOD removals to levels less than 20 mg/l will be required within 10 to 15 years in order to avoid increasing the organic waste loads imposed on receiving waters. Such removals cannot generally be attained by conventional secondary biological treatment processes; hence, more advanced treatment methods will have to be employed.

Much of the increased waste loads in these areas will result from industrial activities and 5-day BOD tests, or even COD tests, may not be realistic indicators of industrial waste loads; therefore, a total carbon index or some other reliable indicator may need to be used along with improved treatment processes in the management of stream quality in these areas.

Because the absolute quantities of pollution additives from rural and urban runoff and from agricultural return flows are unknown, any water quality management plan that is developed at this time must contain a generous safety factor. It is reasonable to expect that the contribution from urban runoff will increase with increasing urban development, and that the contribution from agricultural return flows will increase with increasing use of fertilizers and pesticides.

Under present conditions, only three avenues are available for organic pollution abatement; namely, exhaustive treatment of municipal and industrial effluents, stream reaeration, and low-flow augmentation. Only the first of these three, exhaustive effluent treatment, can be used effectively for nutrient control for all stages of a waterway.

The contribution of other potential pollutants such as heat, dissolved solids, settleable solids, suspended solids, taste-and-odor-causing agents, and short- and long-term toxicants can also be evaluated. The effect of all these materials on the value of water resources can be determined only after appropriate systems analyses and economic evaluations have been made.

The present concentrations of pollutants in streams can be maintained only if the total quantity of pollutants added to the streams remains constant. Hence, increases in waste stream quantities will have to be accompanied by corresponding decreases in the concentrations of pollutants in the waste streams if it is desired to maintain present stream quality. The effluent quality required to maintain present conditions, as shown in Appendix C, is therefore inversely proportional to the projected quantity of return flow, but this may be misleading so far as total solids and chlorides are concerned. Concentrations of chlorides and total solids are lower in some return flows than the present concentrations in the receiving streams. Such is the case of specific effluents in the Wichita Falls Trading Area because of the high concentrations of chlorides in natural watercourses resulting from salt-spring seepage (14).

Based on the data and assumptions contained herein, by the year 2020 most of the return flow will have to be so highly treated for organic and general nutrient removal that it may be an attractive source of water supply, particularly for industrial users. The limiting factor for reuse will be the buildup of dissolved inorganic solids.

Present Effluent Quality

If the present quality of return flows is maintained through the year 2020, the quantity of pollutants released to receiving waters will increase in direct proportion to the increase in return flow quantity. Thus, while the quantity of dilution water available will be reduced through increased consumption, the quantity of pollutants discharged may increase more than threefold. Receiving water quality in year 2020 under such conditions can be expected to be generally poor. Roughly equivalent quality would prevail at the present time if two-thirds of the presently existing waste treatment plants were removed from service.

The significance of the pollutant quantities shown in Appendix D is that removal of these pollutants from return flow may solve the water quality problem, but it will generate a large solid waste disposal problem so far as the removed materials are concerned.

Reduction of Concentrations of BOD and Suspended Solids in Effluents

Since maintaining present effluent quality will result in conditions which are likely to be unacceptable, a projection was made to show the additional quantities of BOD and suspended solids that could be removed by biological treatment processes, Appendix E. Specifically, this projection is the difference between the quantities that would be discharged if the concentrations of 5-day BOD and suspended solids remain constant, and the quantities that would be discharged if the concentrations of 5-day BOD and suspended solids were reduced to 20 mg/l.

It should be noted that industrial quality data are rather incomplete and that figures shown only indicate general ranges. Furthermore, the ultimate BOD would probably be a better indicator of this level of planning. The numbers shown and as printed by the computer may imply a high degree of precision, but this is not the case. Relative relationships are significant in that they indicate the extent to which pollutional characteristics of wastes can be reduced in various areas without the necessity of employing advanced or tertiary treatment processes. The latter process usually indicates an additional advanced form of biological treatment such as denitrification or chemical treatment to remove phosphorus and other undesirable materials.

This projection points up the necessity for obtaining more nearly exact information regarding the quality of effluent streams. Plans for future control measures will be no better than the data on which they are based.

III EFFECTS OF RETURN FLOWS ON SURFACE WATER QUALITY

The present and projected return flows evaluated in the previous chapter are, in most cases, released to the nearest natural watercourse. However, the effluents from approximately 80 municipal treatment plants serving about six percent of the total population of the state are used for irrigation (5), and a much smaller quantity of municipal effluent is used for industrial purposes, as can be seen in Table 2-4. A portion of the municipal effluent that is used for irrigation ultimately becomes return flow from irrigation, and this return flow will contain most of the dissolved inorganic minerals that were in the applied water (15). Hence, no significant degree of accuracy is lost by the assumption that all return flows are released to natural watercourses.

The Texas Water Development Board has established boundaries for 23 drainage basins in Texas. Fifteen of these drainage basins are either rivers or river systems, and the remaining 8 are intervening coastal areas between the mouth of the rivers. Six additional drainage basins, each one encompassing one of the major bay systems and the adjacent 10 to 15 mile wide strip of land around the bay, were defined for this research, Fig. 3-1.

Each city and each county were assigned to the appropriate drainage basin or basins, and the computations previously described for trading areas were repeated for the 29 drainage basins.

Distribution of Return Flows

Approximately 29 percent of the total return flow derived from the use of fresh water in Texas is discharged to the Galveston Bay Basin, as defined above. This percentage is projected to remain practically constant through the year 2020. Another 15 percent of the total return flow is discharged into the Trinity River, which empties into Galveston Bay. Hence, about 44 percent of the total return flow produced in the entire state passes through Galveston Bay on its way to the Gulf of Mexico.

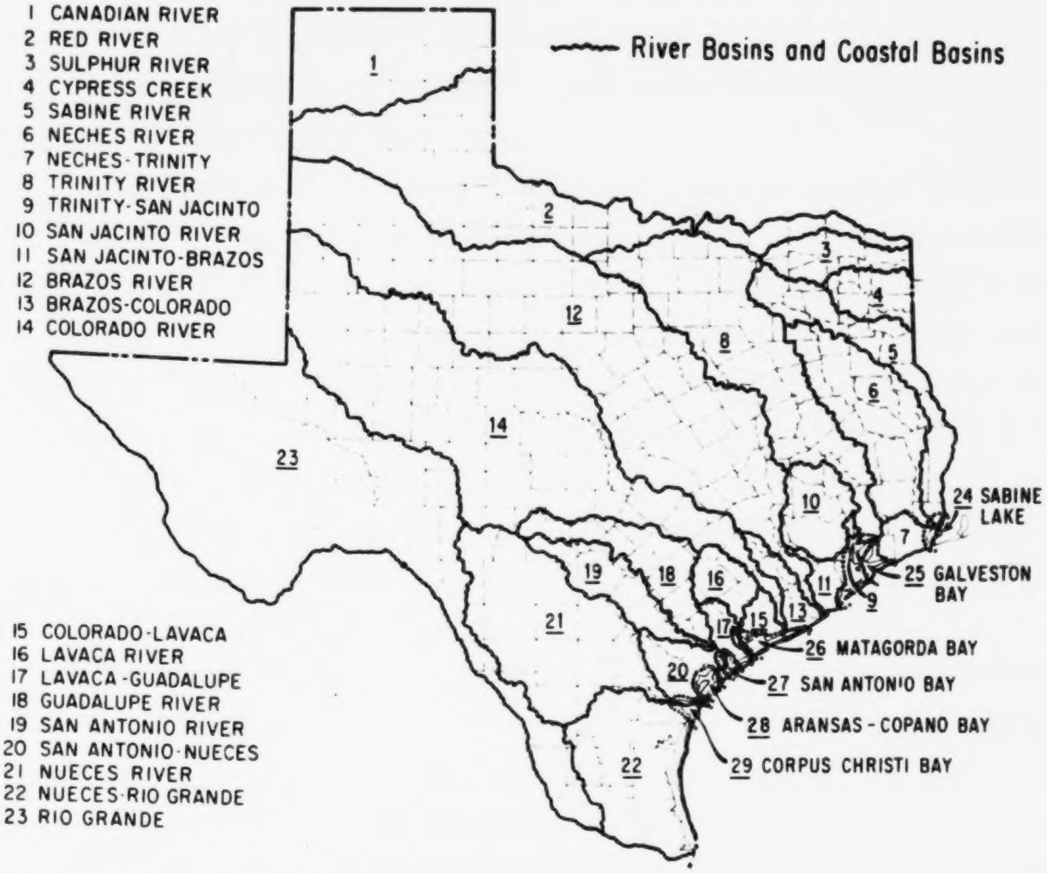
1 CANADIAN RIVER
2 RED RIVER
3 SULPHUR RIVER
4 CYPRESS CREEK
5 SABINE RIVER
6 NECHES RIVER
7 NECHES-TRINITY
8 TRINITY RIVER
9 TRINITY-SAN JACINTO
10 SAN JACINTO RIVER
11 SAN JACINTO-BRAZOS
12 BRAZOS RIVER
13 BRAZOS-COLORADO
14 COLORADO RIVER
River Basins and Coastal Basins
15 COLORADO-LAVACA
16 LAVACA RIVER
17 LAVACA-GUADALUPE
18 GUADALUPE RIVER
19 SAN ANTONIO RIVER
20 SAN ANTONIO-NUECES
21 NUECES RIVER
22 NUECES-RIO GRANDE
23 RIO GRANDE
24 SABINE LAKE
25 GALVESTON BAY
26 MATAGORDA BAY
27 SAN ANTONIO BAY
28 ARANSAS-COPANO BAY
29 CORPUS CHRISTI BAY

FIG. 3-1. LOCATION OF DRAINAGE BASINS IN TEXAS

The Sabine Lake Basin is the next largest recipient of return flow, with 10 percent of the present total and a projected 12 percent in the year 2020. Fourth in order is the Neches River, with about 8 percent of the present discharge and almost 10 percent projected for the year 2020.

These four basins, which include about 11 percent of the total land area of the state, receive about 62 percent of the total municipal and industrial return flow at the present, and this portion is projected to increase to practically two-thirds of the total by the year 2020.

The Brazos, Colorado, San Antonio, and Canadian River Basins together receive about 18 percent of the total return flow, and the remaining 20 percent is contributed to the other 20 basins. Only minor changes in this pattern are projected to occur by the year 2020.

The distributions of both municipal and industrial return flow differ in several cases from that of total return flow, because industry is more highly concentrated along the eastern Gulf Coast than elsewhere. Almost 37 percent of the industrial waste water is released to the Galveston Bay area. Another 15 percent is released to Sabine Lake, and the Neches River gets over 13 percent of the total. Less than 5 percent of the land area of the state is included in these three basins, which together receive almost two-thirds of the total industrial return flow. About 14 percent of the state total is released to the Trinity and Canadian Rivers and Matagorda Bay, leaving approximately 21 percent for the remaining 23 basins.

The Trinity River Basin, at 27 percent, is the leading recipient of municipal return flow, followed by Galveston Bay with 19 percent. The San Antonio and Brazos Rivers receive about 10 and 9 percent, respectively, followed by the Colorado, 7 percent, the Rio Grande, 4 percent, and Sabine Lake, 3 percent. No other basin in the state accounts for as much as 3 percent of the total municipal return flow.

A complete tabulation of present and projected municipal, industrial, and total return flows for each drainage basin is presented in Appendix F. A more detailed breakdown by counties, cities, and zones of river basins can be found in the report "Return Flows, Impact on Texas Bay Systems" (1).

Quality of Return Flows

Quality data developed for trading areas as described previously were also computed for the drainage basins considered in this section. Since most of the estimates of the effects of return flows are based on the assumption that the present effluent quality will be maintained in the future, the quantities of pollutants that will be discharged in the future under this condition are presented in Appendix G.

Effects on Streams

The total effect of the addition of return flow to a stream can probably never be determined, but the gross effect on the parameters of primary interest from a water resources management standpoint will depend on the quantity and quality of the return flow added. Any combination of three fairly distinct generations of quality problems may result from the discharge of wastes into a stream. These three problems are (a) depletion of the dissolved oxygen concentration in the stream as a result of the introduction of degradable organic material, (b) excessive plant growth in the stream resulting from the introduction of inorganic nutrients, and (c) buildup of chlorides or total solids resulting from multiple reuse, evaporation, and excessive concentrations in effluents. All three problems were found to exist in various reaches of different streams in the state.

Only six streams in the state receive significant fractions of the total return flow produced by municipal and industrial water users. These streams are the Trinity, Neches, San Antonio, Brazos, Colorado, and Canadian Rivers. Large scale problems that may result from return flows can logically be expected to be associated with these streams. However, the effect of return flow on a stream depends not only on the quantity and quality of return flow but also on the flow of the stream to which it is introduced. Therefore, problems that are smaller in scale, but no less severe in intensity, may occur in any area of the state. In fact, some 80 municipal waste treatment plants have been reported to discharge their effluents to watercourses which are intermittently dry (5). It is likely that many other plants, particularly in the western area of the state, discharge effluents to streams that are dry periodically during the year, resulting in locally obnoxious stream conditions. From a water quality standpoint, the most serious effect of such conditions may well result from the quantities of dissolved inorganics that are deposited in the stream, to be flushed to downstream reservoirs with the first flood. No effort was made in this research to determine where such conditions exist.

The Trinity and San Antonio Rivers both originate in relatively dry sections of the state, and both are characterized by wide variations of flow, particularly in the upper reaches. Very low dry weather flows may occur in the upper reaches of both streams, and this condition may persist throughout the length of the San Antonio River.

These periodic low flow conditions, combined with the major population centers located near the headwaters of both streams have resulted in quality control problems that provide some insight into the entire water quality management problem.

The large municipal return flow from the Ft. Worth-Dallas area is subjected to secondary biological treatment; nevertheless, because of the low dry-weather flow available in the Trinity, the assimilative capacity of the stream is frequently exceeded, and it has been reported to be devoid of oxygen for about 100 miles below Dallas during dry summer months (16). It does not appear that this condition could be rectified by biological treatment processes. Rather, aside from augmenting the low flow condition by the importation of substantial quantities of dilution water, it appears that advanced treatment by chemical precipitation to remove possibly 98 or 99 percent of the 5-day BOD from effluents might be required in order to maintain aerobic conditions throughout the river. Unless inorganic nutrients were also removed to a similar extent, it seems to be evident that the water quality would remain poor. As mentioned earlier, similar conditions that differ only in scale undoubtedly exist in other areas of the state.

The major water quality control problem of the San Antonio River apparently results from excessive inorganic nutrient concentrations in return flows, rather than from excessive organic pollution. Secondary biological treatment of return flows that are discharged to the stream is followed by oxidation ponds in which most of the remaining BOD is satisfied. The return flow to the river thus contains a low BOD, but relatively high concentrations of inorganic nutrients. As a result, a high algal concentration has been reported to exist in this stream from San Antonio to the mouth (17). It is logical to assume that this same condition would occur in the Trinity if the current problem of DO deficiency were overcome by advanced treatment that did not also remove inorganic nutrients.

Return flows have not adversely affected the Brazos, Neches, and Colorado Rivers to the extent that they have affected the Trinity and San Antonio largely because of three reasons: smaller quantities of return flows, more even distribution, and release in lower reaches where streamflows are higher. Increasing return flow quantities in the future can be expected to affect these streams in exactly the same patterns as the Trinity and San Antonio now display, although it is not possible to foretell the exact degree to which they will be affected.

Agricultural return flows have not been studied in this research, but their importance to the overall management of water quality needs to be noted. For example, essentially the entire flow of the Rio Grande is diverted to agricultural use in the El Paso area. Drainage ditches in the irrigated area maintain the water table a few feet below the ground surface, and return a portion of the spent irrigation water to the river below the city. Chloride concentration in this return flow has been reported to be in excess of 2000 mg/l, about 4 times the concentration in the applied water (15).

The problem of excessive chloride concentration has not yet occurred as a result of municipal and industrial use of water, but it can be seen in Appendix G that the quantity of chlorides projected to be discharged to the Trinity River by the year 2020 could easily cause problems. The onset of these problems will be hastened by the increased evaporation resulting from proposed dams and locks on the river.

Quantities of phosphates estimated in this research to be discharged to various drainage basins, Appendix G, have been found to be in excellent agreement with quantities measured in the streams by Connell (11). For example, quantities estimated in this research for the Trinity, Colorado, Brazos, and San Antonio Rivers are 22, 5, 7, and 9 tons per day, respectively. Quantities reported by Connell on the basis of his measurements were: for the Trinity, from 20 to 25 tons per day; for the Colorado, from 2 to 3 tons per day; for the Brazos, 3 to 4 tons per day; and for the San Antonio, 5 to 7 tons per day.

Effects on Bays and Estuaries

The gross effect of return flows on bays and estuaries is similar to the effect on streams, even to the extent that excessive concentrations of chlorides in return flows may become a problem. Oxygen depletion is likely to be the most important effect of releases directly into a bay, while problems attributable to excessive nutrient concentrations are likely to be predominant in the case of return flows entering via tributaries. An estuary's value as a spawning and nursery area is related to the existence of a well-defined salinity gradient across the estuary, and this gradient may be destroyed by excessive chloride concentrations in return flows (18).

The complex nature of a bay or estuary, with its varying currents caused by wind and tidal action, density gradients, and freshwater inflows, makes the determination of the precise effects of return flows on the system impossible. The problem is complicated by the lack of basic data relative to transport, mixing, reaeration rates, deoxygenation rates, effects of bottom deposits, and many other factors.

Regardless of these inadequacies of data, and of the complexities of the systems involved, a computational model based on many simplifications was developed in order to make estimates of the general effects of projected return flows. When better data become available, refinements can be made, but with present return flows as inputs, the mixing and dissolved oxygen model developed yields results that are in general agreement with presently known conditions, and responds logically to changes in input. Thus, the estimates obtained by using the model are useful for long range planning purposes and they are believed to be at least indicative of the magnitude of the correct results.

The computational model developed was adapted from one previously reported by Frankel (19). Mixing, physical exchange, and biological degradation are accounted for in the model, but the relationships of these phenomena as they are treated in the model to the same phenomena as they occur in a bay are very tenuous in many respects. For example, the tidal prism concept, a first guess at best, was used in computing physical exchange, and the model considers the total exchange so computed to occur in 12 equal increments throughout the day. Mixing of return flows with the waters in a bay is a very complex and variable mechanism, but the model treats it as simple and constant.

Segmentation models and physical exchange coefficients, as well as current velocities, segment volumes, and depths required in the model were estimated by Masch (20). Many inadequacies of available data were noted by Masch, to the extent that except for Galveston and Matagorda Bays, the segmentation models were made largely on the basis of topographic features.

Present and projected return flows to each of the bay drainage basins, as previously defined, were assumed to discharge directly to the nearest segment of the bay, although in fact many of these wastes are discharged into creeks and bayous a few miles from the adjacent bay. Wastes transported into the bays by tributaries were assumed to have been substantially degraded by stream biota by the time they entered the bay. Unpublished data available in the files of the Texas State Department of Health indicate that the BOD of the Trinity River near the mouth may average about 5 mg/l during the summer months (21).

Other variables which were required by the computational model but were not available from any source included the rate of sedimentation of BOD and the BOD exerted by bottom deposits. Both of these variables were judged to have low values because all wastes are given at least primary treatment before release. Typical deoxygenation rates were approximated, as were hourly variations of dissolved oxygen concentration in a bay before the addition of pollution.

Thus, although biological degradation was treated in a fairly sophisticated manner in the model, the input data were of undeterminable accuracy. However, the relative relationships are of importance.

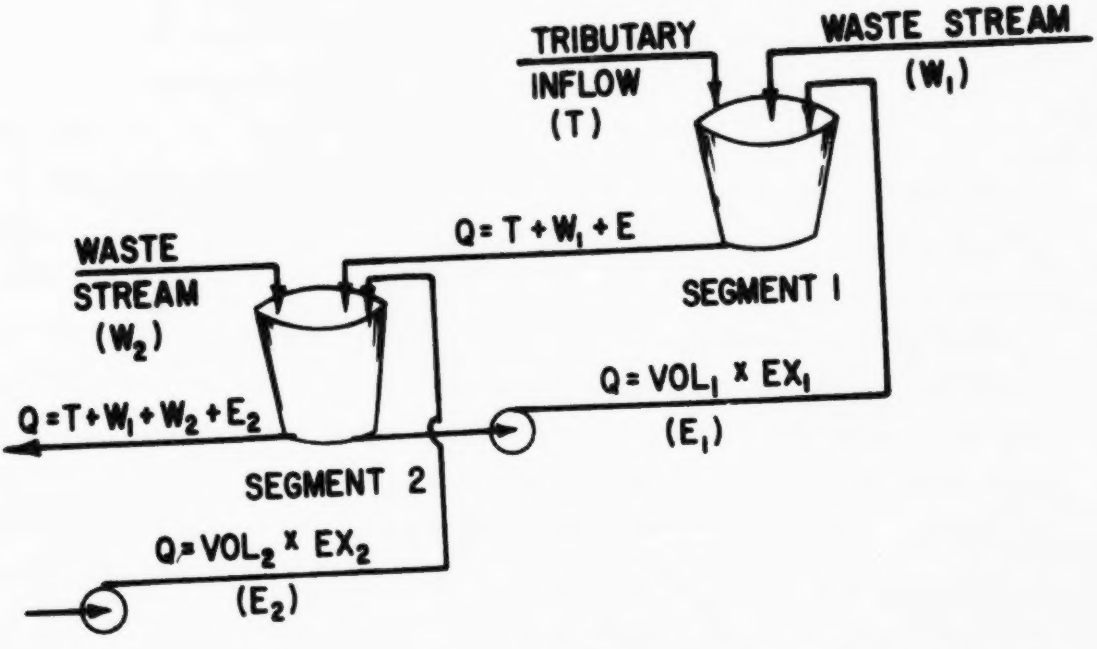
TRIBUTARY INFLOW (T)
WASTE STREAM (W_1)
$Q = T + W_1 + E$
SEGMENT 1
WASTE STREAM (W_2)
$Q = VOL_1 \times EX_1$
(E_1)
$Q = T + W_1 + W_2 + E_2$
SEGMENT 2
$Q = VOL_2 \times EX_2$
(E_2)

FIG. 3-2. ILLUSTRATION OF DISSOLVED OXYGEN AND MIXING MODEL

Each bucket in Fig. 3-2 represents a segment of a bay, and provision was made for adding a waste stream to any segment. In operation, volumes, depths, exchange coefficients, and velocities for each segment of a bay were read into the computer along with all other variables required. Beginning with the uppermost segment in a bay, the waste stream was introduced and the computational procedure was started.

The procedure which was followed converted the volume of each segment into an equivalent flow rate to which the tributary flow rate, waste stream flow rate, and exchange rate were added. These flows were assumed to be completely mixed, and the BOD and DO concentrations of the mixture were determined. Degradation and exchange then proceeded for 24 hours, with new values of BOD and DO being computed each 2 hours. A new cycle was started every two hours to provide for variation in flow rate and concentration of BOD in the waste stream, as well as variations in the DO concentration of the unpolluted bay water.

After 12 such cycles had been run, corresponding to one full day of operation, the 12 final values of BOD and DO were stored for future reference. The entire process was then repeated, using the computed BOD and DO values as the concentrations in bay water. The values of BOD and DO computed for the second day of operation were then compared to those obtained on the first day. If the difference was greater than a small predetermined amount, the new values were stored, and the program was run for another day. This process was repeated until no significant change was noted, that is, until "equilibrium" was attained. The equilibrium values were then printed out, and the computation moved on to the next segment.

For the second segment, the input BOD included the direct return flow to the segment plus the amount added by exchange with the first segment. The computational procedure described for the first segment was then used to find equilibrium values for the second segment, and this entire process was repeated until the mouth of the bay was reached.

The dissolved oxygen concentrations in all segments of all bays were estimated in this manner using present return flow quality with present, 1980, and 2020 projected quantities of return flow.

The program was then revised and used to estimate the quantity of dilution water that would be required to maintain present DO levels with projected return flows. This was accomplished by modifying the program to compute DO values, add water to the return flow and reduce the BOD accordingly, recompute DO values, and repeat this process until the DO values were approximately equal to those estimated for present conditions. The quantity of dilution water estimated to be required by this method should be in the same range of accuracy as the estimated dissolved oxygen concentrations.

Present and projected phosphate concentrations were estimated by means of a much simpler model. Since phosphates are non-degradable, the quantity entering any segment of a bay must be equal to the quantity leaving under long-term equilibrium conditions; so the phosphate concentration in a segment is dependent only on the quantity of water and amount of phosphates crossing the segment boundary.

Galveston Bay: As stated earlier, approximately 44 percent of the entire quantity of return flow produced in the state passes through Galveston Bay. This bay is an important recreational area for the heavy concentration of people in the adjacent area, and it serves as a nursery for over 80 percent of the total poundage of fishery products taken from the Texas Gulf Coast. When these facts are considered along with the heavy industrial concentration and the activity of the Port of Houston, the importance of Galveston Bay to the economy of the entire state is easily recognized.

Partly for the above reasons, and partly because physical data related to Galveston Bay are less incomplete than is the case for other bays, a major portion of the effort in this research was expended in the study of Galveston Bay.

The segmentation model of the bay for a four-mile excursion, Fig. 3-3, was used in estimating present and projected DO concentrations.

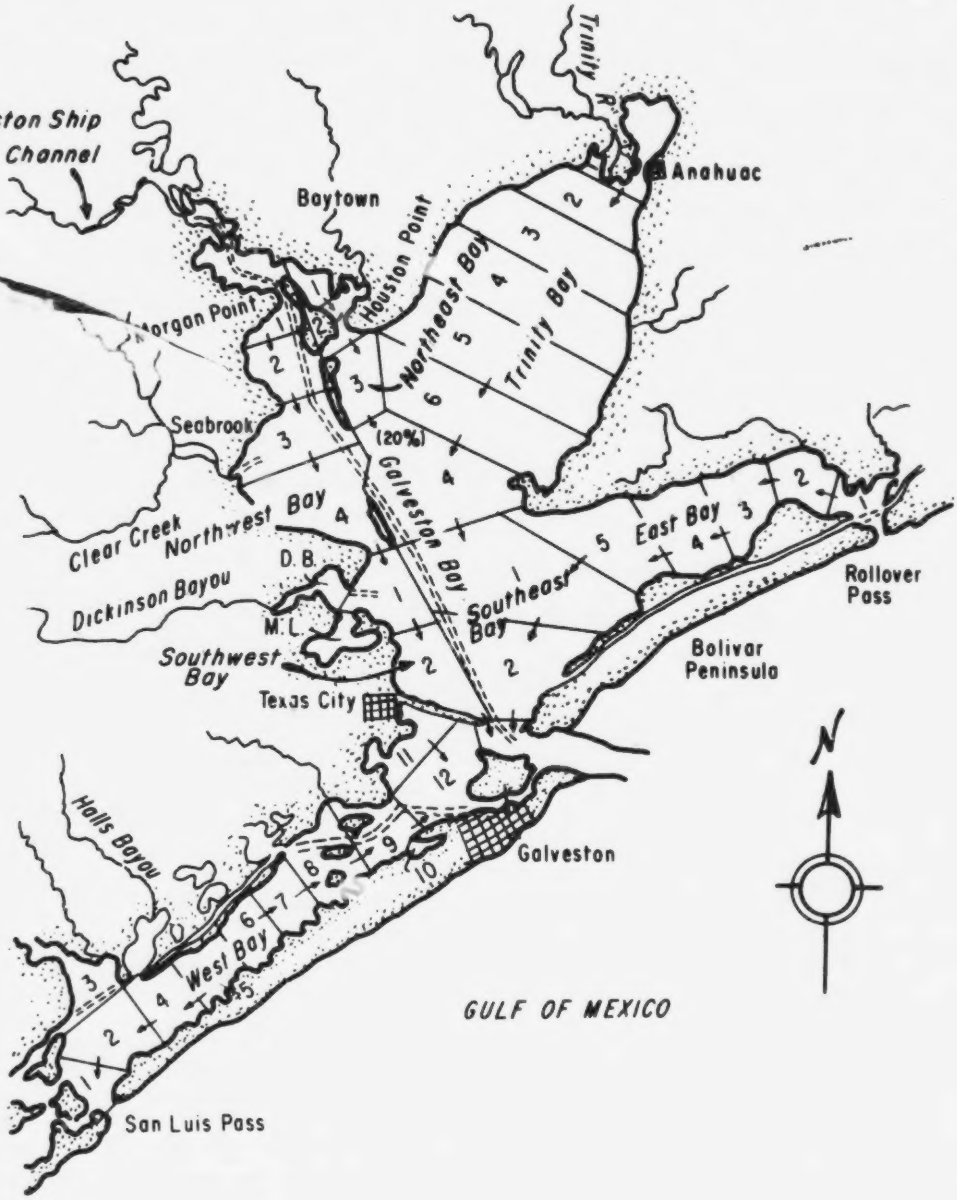
Houston Ship Channel
Baytown
Houston Point
Trinity R.
Anahuac
Morgan Point
Northeast Bay
Trinity Bay
Seabrook
(20%)
Galveston Bay
Clear Creek
Northwest Bay
D.B.
Dickinson Bayou
M.L.
Southwest Bay
Southeast Bay
East Bay
Rollover Pass
Bolivar Peninsula
Texas City
Halls Bayou
Galveston
West Bay
GULF OF MEXICO
San Luis Pass
N

FIG. 3-3. GALVESTON BAY SEGMENTATION MODEL (FOUR MILE EXCURSION) (20)

Most of the direct return flow to the bay enters through the Houston Ship Channel into segment 1 of Northwest Bay, although a substantial quantity is introduced into segments 1 and 2 of Northeast Bay from the Baytown industrial complex. Most of the tributary contribution enters Trinity Bay via the Trinity River.

Present and projected DO concentrations estimated for segments of Galveston Bay are presented in Fig. 3-4. Values shown in Fig. 3-4 represent the 24-hour average concentrations of DO in the full depth of the segments, and these values are in general agreement with reported values (22). Both the diurnal variation and the variation of concentration with depth have been masked by the values presented.

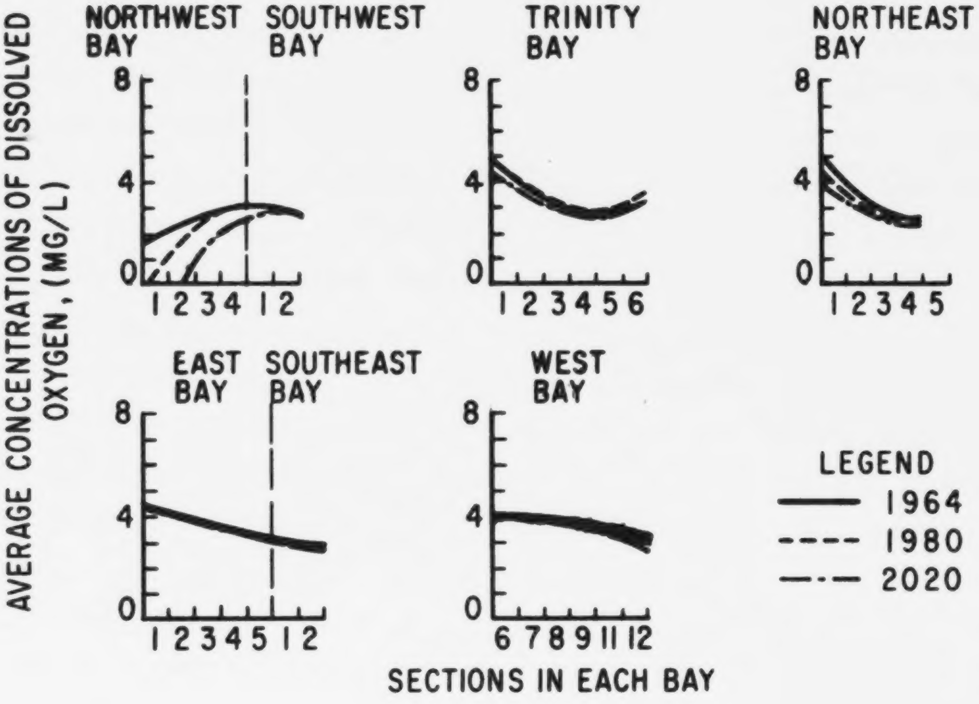

FIG. 3-4. PRESENT AND PROJECTED DO CONCENTRATIONS IN GALVESTON BAY

The concentrations of dissolved oxygen in most regions of the bay can be seen to decrease toward the mouth of the bay. This decrease in dissolved oxygen concentration is the result of increasing water depth. Thus, although DO concentration might be relatively constant at the surface throughout the bay, it is assumed that the concentration decreases with depth. For this reason the average concentration in deep sections is less than that in shallow sections.

The only area of the bay that appears to be deficient in dissolved oxygen at this time is the upper end of Northwest Bay. Similarly, for the projected 1980 and 2020 loading conditions, the only significant effect appears to be a further deterioration of quality in the same area.

Fig. 3-4 may be misleading because a superficial examination of it indicates that no very severe problem exists now, or is projected to exist in the future. However, such is not the case. The 1980 projection for Northwest Bay indicates that 6 or 8 square miles of bay will be practically devoid of dissolved oxygen, and the 2020 projection increases the area to around 20 or 25 miles. In both cases, the entire upper ship channel can be expected to be at least as deficient as the bay. Ten or twenty square miles of septic bay, plus 15 or 20 miles of septic channel surely could constitute at least a major aesthetic problem.

Dilution water that would be required to maintain present dissolved oxygen levels, which levels appear to marginal at best in some areas, was estimated to be about one million acre feet per year in 1980, and about three million acre feet per year in 2020. Obviously this is an expensive use of fresh water.

Present and projected phosphate concentrations throughout the bay are presented in Fig. 3-5. As was the case with dissolved oxygen concentrations, values computed by the model were in general agreement with observed values (23). Again, Northwest Bay is shown to be the greatest problem area, but concentrations that are likely to result in luxuriant algal growth are projected to occur in all areas of the bay by the year 2020.

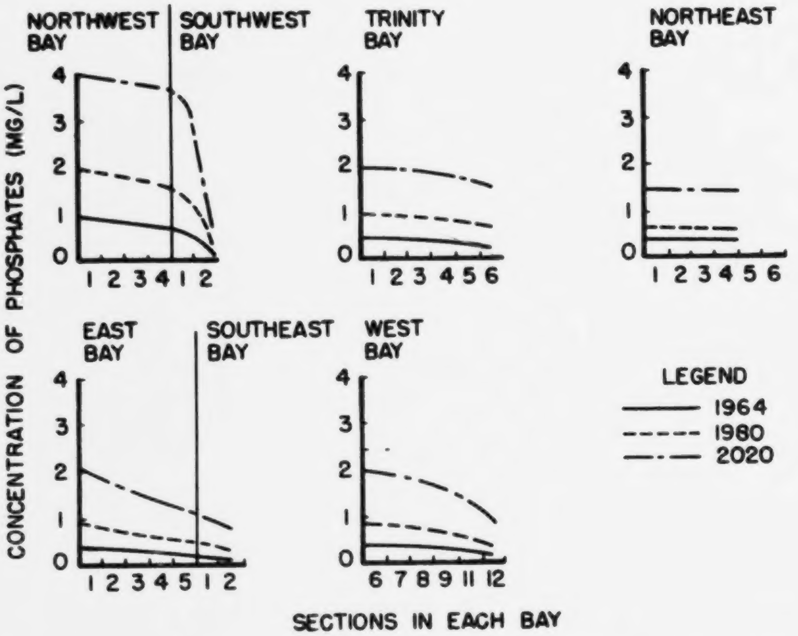

FIG. 3-5. PRESENT AND PROJECTED PHOSPHATE CONCENTRATIONS IN GALVESTON BAY

Three million acre feet of dilution water per year were estimated to be required in order not to exceed present phosphate concentrations in the bay for projected 1980 loading conditions. Twelve million acre feet per year were estimated to be required for the same purpose in the year 2020. It thus appears that much less dilution water would be required to maintain present dissolved oxygen levels in the bay than would be required to maintain present phosphate concentrations.

Matagorda Bay: Return flows to Matagorda Bay are low in quantity, and are reported to be of good quality. For example, present total return flow to the bay amounts to about seven percent of the return flow to Galveston Bay, but the total BOD discharged is only about two percent of the quantity discharged in Galveston Bay. For these reasons, dissolved oxygen concentrations in Matagorda Bay, Fig. 3-6, were estimated to be satisfactory for the present and projected 1980 and 2020 return flows.

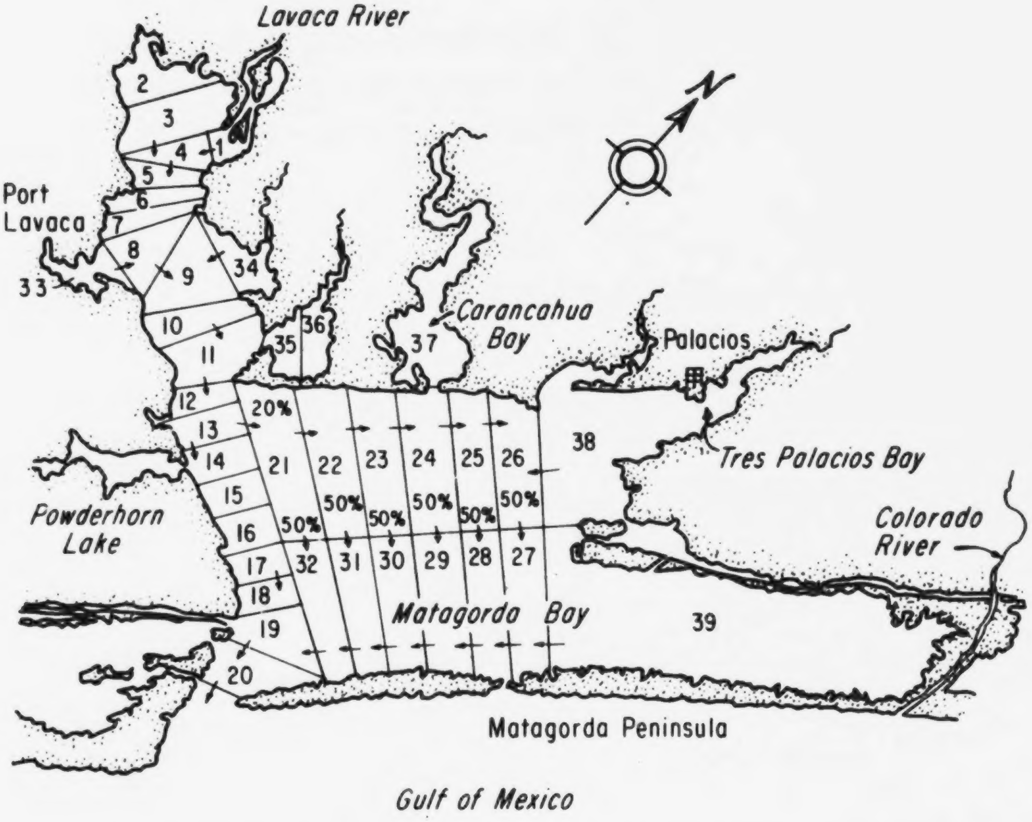
Lavaca River
N
2
3
4
1
5
6
Port Lavaca
7
8
9
34
33
10
11
35
36
37
Carancahua Bay
Palacios
12
20%
13
14
21
22
23
24
25
26
38
Tres Palacios Bay
15
50%
50%
50%
50%
50%
50%
Powderhorn Lake
16
17
32
31
30
29
28
27
Colorado River
18
19
Matagorda Bay
39
20
Matagorda Peninsula
Gulf of Mexico

FIG. 3-6 MATAGORDA BAY SEGMENTATION MODEL (20)

The present phosphate concentrations were estimated to range from about 0.6 mg/l in segment seven to about 0.1 mg/l in segment twenty. These fairly high values result from a relatively minor quantity of return flow because of the low exchange coefficients assumed for the bay. Respective values for the same segments were estimated to be 0.8 mg/l and 0.2 mg/l in 1980, and 0.9 mg/l and 0.3 mg/l in 2020.

In this bay, the increased quantity of return flow projected for 1980 and 2020 provides additional flushing action and prevents phosphate concentrations from increasing approximately linearly with return flow, as is the case in most of the other bays.

It was estimated that about 50,000 acre feet of dilution water per year in 1980, and about 100,000 acre feet per year in 2020 would be required to maintain present phosphate concentrations.

Aransas-Copano-San Antonio Bays: San Antonio Bay, Fig. 3-7, is the direct recipient of only minor quantities of return flow. Hence no deficiencies of dissolved oxygen concentration were estimated from present or future return flows.

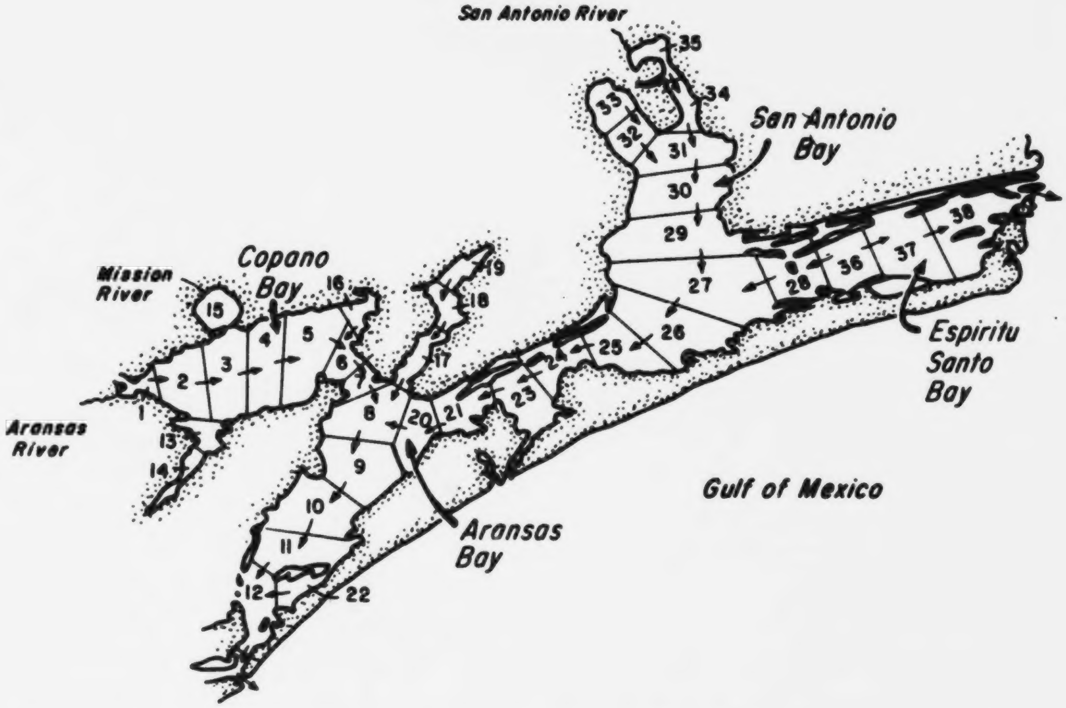
San Antonio River
35
34
33
32
31
30
29
San Antonio Bay
38
37
36
28
27
26
25
24
23
21
20
Copano Bay
16
Mission River
15
19
18
17
5
4
3
2
6
7
8
1
Aransas River
13
14
9
10
11
12
22
Espiritu Santo Bay
Gulf of Mexico
Aransas Bay

FIG. 3-7. ARANSAS-COPANO-SAN ANTONIO BAYS SEGMENTATION MODEL (20)

Large quantities of phosphates are transported into the bay by the San Antonio River, resulting in an estimated phosphate concentration of about 6 mg/l in segment 35 of the bay and a concentration of about 3 mg/l at the mouth. Corresponding values for 1980 and 2020 were estimated to be about 1.5 and 2.5 times present values.

Dilution water required to maintain present concentrations was estimated to be 200,000 acre feet in 1980, and 650,000 acre feet in 2020, although it should be noted that there does not appear to be any particularly good reason for maintaining such a high phosphate concentration as 6 mg/l.

The Aransas-Copano Bay system was estimated to have no present or future problems other than those attributable to its interchange with San Antonio Bay. By the same token, maintaining the present quality in San Antonio Bay will automatically maintain present quality in the Aransas-Copano Bay system.

Corpus Christi Bay: No widespread oxygen deficiency was estimated to occur in Corpus Christi Bay, Fig. 3-8, for either present or projected 1980

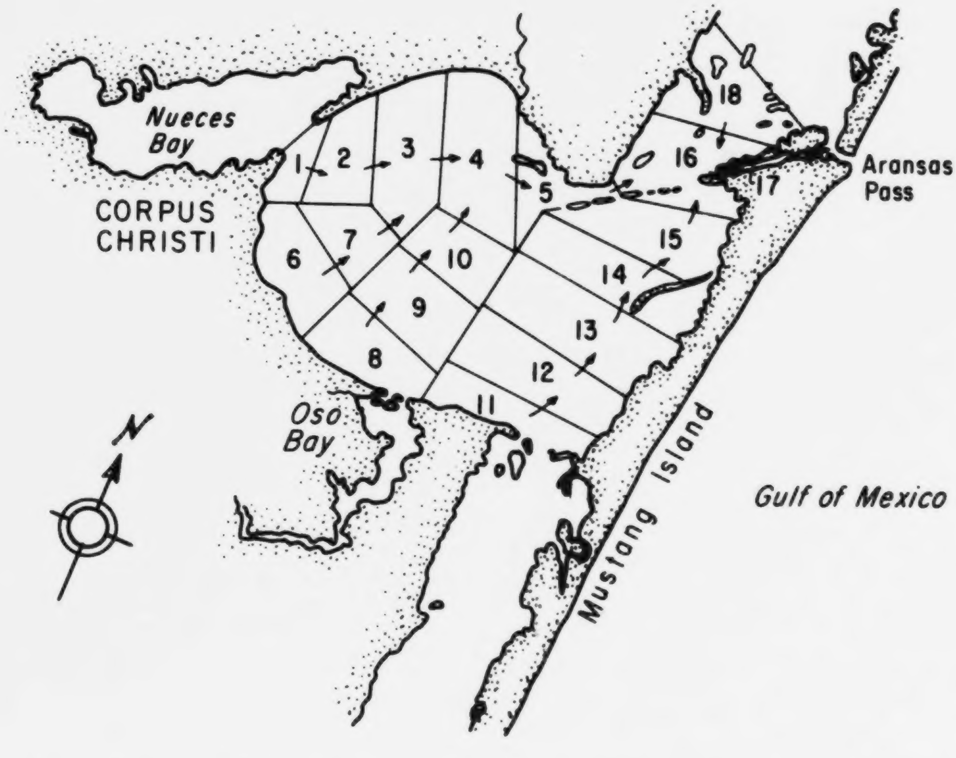
Nueces Bay
CORPUS CHRISTI
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Aransas Pass
Oso Bay
N
Mustang Island
Gulf of Mexico

FIG. 3-8. CORPUS CHRISTI BAY SEGMENTATION MODEL (20)

return flows. For the predicted 2020 return flow however, a marked decrease in dissolved oxygen level was noted in segment 6 of the bay.

Phosphate concentrations were estimated to be much higher at the present than is the case for Galveston Bay, ranging from about 5 mg/l in segment 6 to about 0.9 mg/l at the mouth.

Return flows to Corpus Christi Bay were projected to increase to about 1.9 times their present value by 1980 and to about 3.5 times their present values by 2020, and phosphate concentrations are estimated to increase accordingly. On the basis of the model used, it was estimated that about 700,000 acre feet of dilution water would be required per year to maintain present quality in 1980, and about 1.6 million acre feet per year would be required in 2020.

IV OPTIMIZATION ANALYSIS

The purpose of the research discussed in this section was to develop a generally applicable, flexible computational system for minimizing the total cost of maintaining a stream standard related to non-degradable pollutants, where a number of cities are located along a stream and are discharging wastes to it. Steady state conditions were assumed to exist, and the stream standards were assumed to be known.

The computer program developed was designed specifically for maintaining a standard related to phosphate concentration, but adapting it to any other non-degradable pollutant would simply require changing of the cost function used. The program could also be made applicable to a degradable pollutant with only slight modification.

Frankel has shown that as a general rule for biologically degradable pollutants, downstream water treatment is a less costly method of maintaining water quality in a downstream user's distribution system than is upstream waste treatment (19). Recent work by Thomas and Spofford illustrates the value of making use of a stream's transit storage time, exchange capacity, coagulant aid effect, and dilution capacity in regulating the concentration of a radioactive element in a downstream user's distribution system (24).

Unpublished work by Dr. C. S. Beightler indicates that for non-degradable wastes, the maintenance of quality in a given water distribution system can be accomplished more economically by downstream water treatment than by upstream waste treatment (25). This effect was much more pronounced when a reservoir in which evaporation considerably exceeded rainfall was added between the waste discharger and the water user, because of concentration of the pollutant by evaporation of water from the reservoir. It therefore appears that for either conservative, biologically degradable, or radioactive wastes, the prime function of waste treatment in general is the maintenance of stream standards, rather than the avoidance of water treatment costs. If drinking water standards with respect to a particular pollutant are only very slightly higher than are stream standards for the same pollutant, it is possible that the optimum solution would be to increase upstream waste treatment slightly in order to avoid downstream treatment costs.

The determination of fully optimum stream standards is, according to Kneese, an unattainable goal (26). Lack of demonstrable optimality in the establishment of future stream standards does not preclude the possibility, nor lessen the desirability, of determining the optimum means of meeting whatever standard may be established. Indeed, a convenient method of computing the cost of meeting any particular standard would be helpful in determining what standards should be adopted.

Nature of the Problem

A stream which serves as a source of supply and a recipient of wastes for a number of cities located along its length, and in which a given water quality must be maintained, is a serial multistage system in which a series of decisions must be made in sequence. Each stage of this system includes a reach of the stream with natural inflow and evaporation and a city that withdraws water from the stream or other sources, adds pollutants to a portion of the withdrawn water, and returns this polluted portion to the stream. At each stage, a decision must be made regarding the quantity of pollutant to be removed before returning the waste to the stream, and any particular decision has a particular cost associated with it. Also, the decision made at each stage affects the circumstances under which the next decision in sequence will be made. Hence, if more pollutant is removed at one city than that required to meet the stream criteria, the amount that must be removed at the next city will be decreased.

If M possible degrees of treatment were considered at each of N cities located along a reach of stream, a total of M^N permutations of degrees of treatment would exist. Finding the minimum cost for maintaining a stream standard by direct comparison of all possible permutations would be a very tedious, if not impossible, task unless both M and N were fairly small.

Optimization Technique

The serial multistage system shown in Fig. 4-1 represents a reach of stream which is divided into N stages by the location of N cities along the stream. In the figure the stage influent and effluent concentrations are respectively represented by I_i, i=1, ..., N, and E_i, i=1, ..., N. Similarly, the decision to be made and the returns (costs) associated with the decisions are respectively represented by D_i, i-1, ..., N, and R_i, i=1, ...N. The CA_i, i=2, ... N+1 are the allowable stream concentrations.

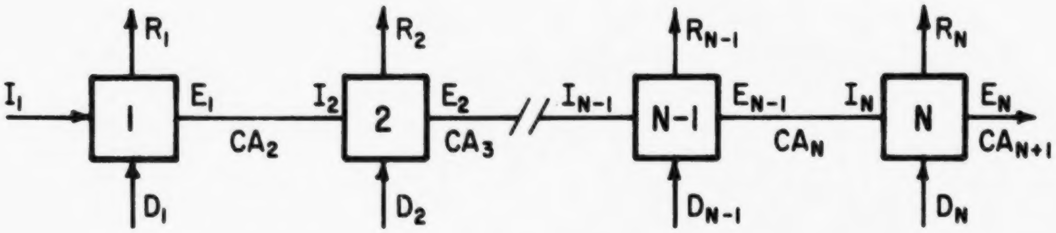

FIG. 4-1. BLOCK DIAGRAM FOR REACH OF STREAM

For the system shown, the objective is to minimize the function $\hat{R} = \sum_{i=1}^{N} R_i$ where $\hat{R}$ is the total cost, subject to the restriction,

$$0 \leq E_i \leq CA_{i+1}, \; i=1, \ldots N.$$

The following functional relationships can be determined from observation of Fig. 4-1:

$$R_i = F(I_i, D_i) \qquad , \; i-1, \ldots, N$$

$$D_i = G(I_i, E_i) \qquad , \; i=1, \ldots, N$$

$$I_i = H(E_{i-1}) \qquad , \; i=2, \ldots, N$$

$$E_i = W(I_i) \qquad , \; i=1, \ldots, N$$

The value of the I_i, $i=1,\ldots,N$, must also lie between 0 and CA_i, $i=1,\ldots,N$.

At stage N, the optimal return, $f_n(D_n)$, is a function of the input and decision at this stage only; thus,

$$f_n(D_n) = \min_{0 \le D_n \le CA_n} F(I_n, D_n)$$

Similarly, the optimal return at stage N-1, including stages N and N-1, can be seen to be:

$$f_{n-1}(D_{n-1}) = \min_{0 \le D_{n-1} \le CA_{n-1}} F(I_{n-1}, F_{n-1}) + f_n(D_n),$$

or substituting,

$$= F(I_{n-1}, D_{n-1}) + f_n \left[G\left\{H\ (E_{n-1}),\ W[H\ (E_{n-1})]\right\}\right]$$

In general, then the total optimum return at any stage, including all subsequent stages is,

$$f_i(D_i) = \min_{0 \le D_i \le CA_i} F(I_i, D_i) + f_{i+1}\left[G\left\{H(E_i),\ W[H(E_i)]\right\}\right], \quad i=1,\ldots N-1,$$

and for the entire system the optimum return, $\hat{R}^*$, becomes:

$$\hat{R}^* = f_1(D_1).$$

Following Bellman's dynamic programming procedure as outlined above, the number of permutations that must be considered in finding the optimum solution is reduced from M^N to NM^2, and only N problems must be solved in order to accomplish this (27). The solution of these N essentially identical problems is a repetitive process that is ideally suited to the capability of an electronic computer.

The computational procedure employed can be explained most easily by means of a very simple example illustrated in Fig. 4-2.

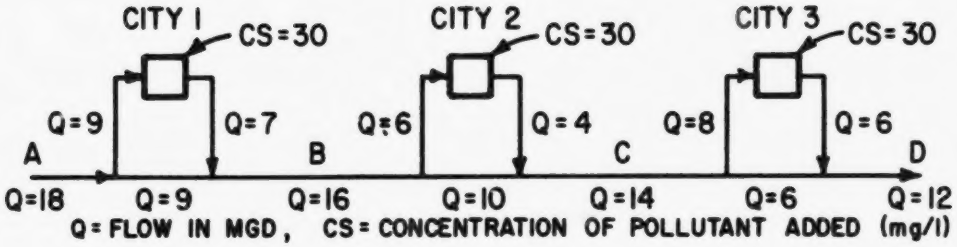

FIG. 4-2. SIMPLIFIED STREAM SYSTEM

For illustrative purposes, the following conditions are assumed:

1. Pollutant concentration added at each city = 30 mg/l
2. Maximum permissible concentration at points B, C, and D = 9 mg/l, but effluent charges are levied if concentration at point D exceeds 2 mg/l
3. Charge = \$144 if concentration at point D = 5 mg/l
4. Charge = \$242 if concentration at point D = 9 mg/l
5. Concentration at point A = 1 mg/l
6. At any plant the first 50 gal of pollutant removed costs \$3/gal, the next 150 gal removed costs \$2/gal, and all additional removal costs \$1/gal. The concentration at point B must be either 1, 5, or 9 mg/l; at point C, it must be either 3, 6, or 9 mg/l, and at point D it must be either 2, 5, or 9 mg/l.

The quantities of pollutants that would have to be removed at each city to meet all combinations of concentrations considered are shown in Tables 4-1, 4-2, and 4-3, which also show the costs associated with each quantity.

In tables 4-1, 4-2, and 4-3, infeasible solutions are indicated by the ∞ symbol.

At city 3, effluent charges of \$144 and \$242 are associated with effluent concentrations of 5 and 9 mg/l, respectively. If these effluent charges are added to the appropriate costs shown in Table 4-3, the total

Table 4-1. Pollutant Removal Required and Cost of Removal at City 1

Influent Concentration (mg/l)	Effluent Concentration (mg/l) 1 Removal (Gal)	1 Cost ($)	5 Removal (Gal)	5 Cost ($)	9 Removal (Gal)	9 Cost ($)
1	210	410	146	342	82	214

Table 4-2. Pollutant Removal Required and Cost of Removal at City 2

Influent Concentration (mg/l)	Effluent Concentration (mg/l) 3 Removal (Gal)	3 Cost ($)	6 Removal (Gal)	6 Cost ($)	9 Removal (Gal)	9 Cost ($)
1	92	234	50	150	8	24
5	∞	∞	106	264	64	178
9	∞	∞	∞	∞	120	290

Table 4-3. Pollutant Removal Required and Cost of Removal at City 3

Influent Concentration (mg/l)	Effluent Concentration (mg/l) 2 Removal (Gal)	2 Cost ($)	5 Removal (Gal)	5 Cost ($)	9 Removal (Gal)	9 Cost ($)
3	192	392	156	356	108	266
6	∞	∞	192	392	144	338
9	∞	∞	228	428	180	380

costs for any combination of influent and effluent concentrations at city 3 will be those shown in Table 4-4.

Table 4-4. Total Cost of Treatment and Effluent Charges at City 3

Influent Concentration (mg/l)	Effluent Concentration (mg/l)		
	2	5	9
	Cost of Treatment ($)		
3	392	500	508
6	∞	536	580
9	∞	572	622

It can be seen in Table 4-4 that if the influent concentration to City 3 were 3 mg/l, the optimum decision would be to reduce the effluent concentration from City 3 to 2 mg/l, and avoid paying the effluent charges. If the influent concentration were either 6 or 9 mg/l, the optimum policy would be to discharge at 5 mg/l concentration and pay only $144 in effluent charges. These optimum policies are tabulated in Table 4-5.

Table 4-5. Optimum Policy at City 3

Influent Concentration (mg/l)	Cost ($)	Effluent Concentration (mg/l)
3	392	2
6	536	5
9	572	5

Since the optimum policy to be followed for any possible influent concentration at point C has been found, these optima can be added to the costs associated with the corresponding effluent concentrations for City 2, (Table 4-2), and the optimum policy for the combined stages can be determined, Tables 4-6 and 4-7.

Hence, regardless of the influent concentration at City 2, the optimum policy for Cities 2 and 3 will be to discharge from City 2 at a concentration of 9 mg/l.

Table 4-6. Total Cost of Treatment and Effluent Charges for Cities 2 and 3

Influent Concentration (mg/l)	Effluent Concentration (mg/l)		
	3	6	9
	Cost of Treatment ($)		
1	626	686	596
5	∞	798	750
9	∞	∞	862

Table 4-7. Optimum Policy at City 2, Including City 3

Influent Concentration (mg/l)	Cost ($)	Effluent Concentration (mg/l)
1	596	9
5	750	9
9	862	9

Proceeding upstream to City 1 it is seen, Table 4-8, that the minimum cost for the entire system under the conditions assumed is $1006 per unit time, and that this cost is associated with an effluent concentration from City 1 of 1 mg/l.

Tracing back through Tables 4-5 and 4-7, the minimum cost is found to occur if the operating policy is that shown in Table 4-9.

Table 4-8. Total Cost of Treatment and Effluent Charges for all Cities

Influent Concentration (mg/l)	Effluent Concentration (mg/l) 1	5	9
	Cost of Treatment ($)		
1	1006	1092	1076

Table 4-9. Optimum Operating Policy for System

Point	Concentration (mg/l)
B	1
C	9
D	5

It should be emphasized that this optimum solution applies only to the assumed possible conditions. If more freedom of choice were permitted at each stage, a more economical solution could undoubtedly be found, but the computational procedure would be exactly the same.

Program Development

Each of the blocks shown in Fig. 4-1 represents a reach of stream similar to that shown schematically in Fig. 4-3. The program developed was dimensioned to optimize up to 30 such reaches on the main stem and each of as many as 6 tributaries of a stream.

The computational procedure used was started by reading the streamflow and pollutant concentration at the upper end of the upstream tributary into the computer. Next, all required input data for each city on the tributary were read into the computer in sequence, and all other variables shown in Fig. 4-3 except T were calculated. The minimum possible concentration attainable at the lower end of each reach was computed, and the range between this value

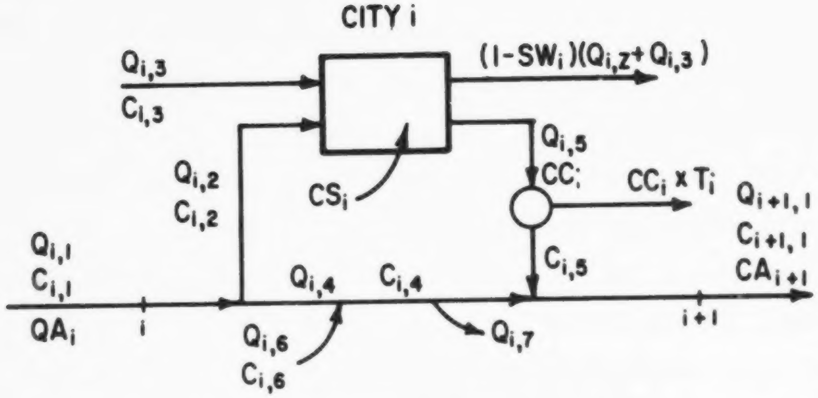
CITY i
$Q_{i,3}$
$C_{i,3}$
$(1-SW_i)(Q_{i,2}+Q_{i,3})$
$Q_{i,5}$
CC_i
$CC_i \times T_i$
$Q_{i+1,1}$
$C_{i+1,1}$
CA_{i+1}
$Q_{i,2}$
$C_{i,2}$
CS_i
$Q_{i,1}$
$C_{i,1}$
QA_i
i
$Q_{i,4}$
$C_{i,4}$
$C_{i,5}$
i+1
$Q_{i,6}$
$C_{i,6}$
$Q_{i,7}$

FIG. 4-3. SCHEMATIC REPRESENTATION FOR A REACH OF STREAM

Symbols used in Fig. 4-3 are the following:

i - Reach number in stream
Q_i, 1** - Streamflow at upper end of reach
2* - Streamflow diverted to city
3* - Other supply to city
4 - Streamflow bypassing city
5 - Return flow from city
6* - Inflow per mile of stream
7* - Evaporation per mile of stream
C_i, 1** - Pollutant concentration at upper end of reach
2 - Pollutant concentration in diverted streamflow
3* - Pollutant concentration in other supply
4 - Pollutant concentration in bypassing streamflow
5 - Pollutant concentration in return flow after treatment
6* - Pollutant concentration in inflow
CC_i - Concentration in return flow before treatment
CS_i * - Pollutant concentration added by city
T_i - Fraction of pollutant removed at treatment plant
D_i * - Length of reach in miles
SW_i * - Ratio of return flow to water use at city
CA_i * - Allowable concentration at control plant
* - Input data required for each reach
** - Input data required for reach 1

and the allowable concentration at the same point was divided into 10 equal increments, with the incremental values being stored for later use.

These incremental values were later used as the input concentrations for the adjacent downstream reach, and as output concentrations for the upstream reach.

This same procedure was followed for all tributaries, then, with a slight modification, for the main stem. For the main stem, each tributary was treated as though it were a city which was supplied from other sources.

The optimization procedure was started at the farthest downstream stage on the main stem by computing the cost of meeting each of the 10 possible effluent concentrations for each of the 10 permissible influent concentrations. The optimum effluent concentration was then chosen for each of the 10 permissible influent concentrations, and these optima were stored in the computer in the manner illustrated in Table 4-5.

At the next stage upstream, the cost of meeting each of the 10 effluent concentrations for each of the 10 influent concentrations was computed. Then since the effluent concentrations for this stage were identical to the influent concentrations for the last stage, the previously stored optima were added to the appropriate costs for the various effluent concentrations.

Again, the optimum effluent concentration was chosen for each influent concentration, and these optima were stored in the manner previously described. It is essential that these latter optima be recognized as including both the last and the next to last stages.

An identical procedure was followed for all other stages until the entire system had been completed. The optimum value found in this manner at the farthest upstream reach is, by the theory previously developed, the optimum value for the entire system under the assumed possible conditions.

The procedure followed for stages that were tributaries, rather than cities, was identical in concept, but somewhat different in detail from that described above. Briefly, it consisted of computing the optimum policies to be followed for 10 possible tributary effluent concentrations. The best of these 10 possibilities was then selected for each of the 10 main stem stage effluent concentrations associated with each of the 10 stage influent concentrations considered. Thus, only 10, rather than the normal 100, different costs were considered for main stem stages that were tributaries.

An obvious shortcoming of the procedure thus far developed is that removals at each stage have been assumed to be variable in only 10 incremental values, while in theory they are continuously variable from zero to complete removal. In order to overcome this shortcoming, the range of permissible concentrations at each control point was narrowed to 0.2 of the original range after the optimum solution under the assumed conditions was found. The new range limits set at each control point were the optimum value for that point plus and minus 0.1 times the original range. A new optimum was found, the range was again narrowed, and this procedure was repeated for as many times as the total cost could be significantly reduced. Usually, not more than three repetitions were required for any system. Three repetitions effectively divides the permissible range at each point into 1250 increments.

Four hundred cost computations at each stage of the main stem, and 4000 cost computations at each stage of each tributary were thus required to obtain the solution by this method. More than 1.6 million computations at each stage of the main stem, and more than 16 million at each stage of each tributary would have been required to obtain results with the same degree of accuracy if the original permissible range at each control point had been divided into 1250 increments in the beginning. Computation time was thus reduced by a factor of over 4000 by the dynamic programming method.

Practical Application

Twenty seven cities are located along the main stem and 5 tributaries of the Trinity River in the Fort Worth - Dallas area, Fig. 4-4. Preliminary

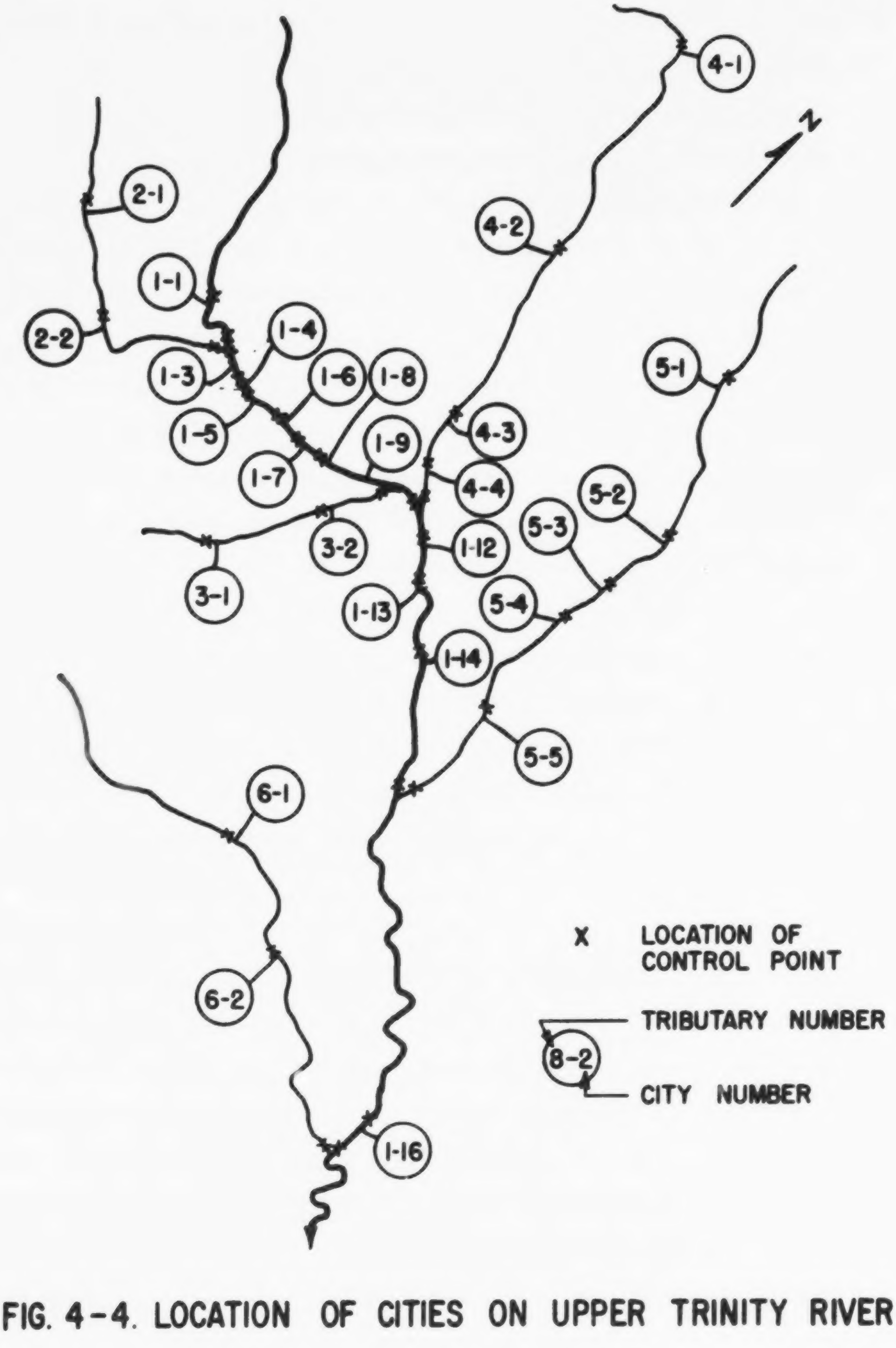
4-1
N
2-1
4-2
1-1
2-2
1-4
1-3
1-6
1-8
5-1
1-5
4-3
1-9
1-7
4-4
5-2
5-3
1-12
3-2
3-1
1-13
5-4
1-14
5-5
6-1
X LOCATION OF CONTROL POINT
TRIBUTARY NUMBER
8-2
CITY NUMBER
6-2
1-16

FIG. 4-4. LOCATION OF CITIES ON UPPER TRINITY RIVER

estimates of the flow in various reaches of these streams reflecting 2010 conditions have been made by the Bureau of Reclamation, and these figures were reduced to an inflow-per-mile basis in order to fit the program (28). Average values of phosphate concentrations in runoff from agricultural lands were obtained from the literature, and both the projected water use in and return flows from the 27 cities for the year 2010 were obtained as described earlier (29).

These and other required data were punched on cards and the program was used to determine the optimum treatment policy for maintaining concentrations of one and two mg/l in the stream. Results for the one mg/l allowable are shown in Table 4-10, while Table 4-11 shows results for the two mg/l allowable concentration. These two assumed allowables are entirely arbitrary, and are shown only for the purpose of demonstrating that greater relative savings are made possible by the greater flexibility inherent in a higher allowable concentration.

For the one mg/l allowable concentration, the total cost of the optimum system can be seen to be about 2.3 percent less than the total cost of the normal system of requiring each city to just meet the allowable. This saving in cost is accompanied by a substantial improvement in the quality of the water in more than half the reaches of the stream. These two factors together make the system much more attractive.

Appraisal of Results

The results obtained demonstrate the desirability of using optimization techniques rather than effluent standards as a means of maintaining stream standards. The entirely arbitrary stream standards used in the program and the relatively simple cost function used do not detract from the method described. Any other cost function that provides for scale economy would yield similar results, although the magnitude of the resultant saving would depend upon the variation of unit cost with size of plant. Similarly, the magnitude of the possible saving through optimization is dependent on the allowable

Table 4-10. **Comparison of Optimum and Normal Treatment Cost for Maintaining Stream Standard of 1 mg/l in Upper Trinity River**

		Normal System			Optimum System		
		Concentration (mg/l)			Concentration (mg/l)		
Trib. No.	City No.	Influent	Effluent	Cost ($)	Influent	Effluent	Cost ($)
2	1	0.10	1.00	359	.10	1.00	359
	2	1.00	1.00	166	1.00	.99	166
3	1	0.10	1.00	468	.10	.06	504
	2	1.00	1.00	351	.06	.99	313
4	1	0.10	1.00	205	.10	.20	319
	2	1.00	1.00	956	.20	.18	1014
	3	1.00	1.00	1013	.18	.14	1058
	4	1.00	1.00	286	.14	1.00	0
5	1	0.10	1.00	450	.10	.89	455
	2	1.00	1.00	1207	.88	.37	1255
	3	1.00	1.00	1448	.37	.22	1509
	4	1.00	1.00	883	.22	1.00	754
	5	1.00	1.00	544	1.00	.99	547
6	1	0.10	1.00	274	.10	1.00	274
	2	1.00	1.00	496	1.00	1.00	496
1**	1	0.10	.47	0	.10	.47	0
	2*	0.47	1.00	-	.47	.53	-
	3	1.00	1.00	7303	.53	.10	7634
	4	1.00	1.00	316	.10	.19	265
	5	1.00	1.00	108	.19	.31	0
	6	1.00	1.00	628	.31	.30	654
	7	1.00	1.00	1373	.30	.27	1433
	8	1.00	1.00	660	.27	1.00	63
	9	1.00	1.00	971	1.00	1.00	971
	10*	1.00	1.00	-	1.00	1.00	-
	11*	1.00	1.00	-	1.00	1.00	-
	12	1.00	1.00	14121	1.00	.79	14406
	13	1.00	1.00	250	.79	.89	0
	14	1.00	1.00	231	.89	.98	0
	15*	1.00	1.00	-	.98	.97	-
	16	1.00	1.00	110	.97	1.00	0
	17	1.00	1.00	-	1.00	1.00	-
		Totals		35177			34449

* Main stem stages that are tributaries ** Tributary #1 is the main stem

Table 4-11. Comparison of Optimum and Normal Treatment Cost for Maintaining Stream Standard of 2 mg/l in Upper Trinity River

Trib. No.	City No.	Normal System			Optimum System		
		Concentration (mg/l)		Cost ($)	Concentration (mg/l)		Cost ($)
		Influent	Effluent		Influent	Effluent	
2	1	0.10	2.00	328	0.10	2.00	328
	2	2.00	2.00	157	2.00	2.00	157
3	1	0.10	2.00	429	0.10	0.06	504
	2	2.00	2.00	336	0.06	1.98	254
4	1	0.10	2.00	51	0.10	2.00	51
	2	2.00	2.00	888	2.00	1.48	980
	3	2.00	2.00	966	1.48	1.20	1052
	4	2.00	2.00	270	1.20	2.00	0
5	1	0.10	2.00	406	0.10	0.08	491
	2	2.00	2.00	1158	0.08	0.04	1255
	3	2.00	2.00	1386	0.04	0.03	1509
	4	2.00	2.00	846	0.03	0.02	919
	5	2.00	2.00	523	0.02	2.00	93
6	1	0.10	2.00	195	0.10	2.00	195
	2	2.00	2.00	451	2.00	2.00	451
1**	1	0.10	0.47	0	0.10	0.47	0
	2*	0.47	2.00	-	0.47	0.64	-
	3	2.00	2.00	6993	0.64	0.12	7637
	4	2.00	2.00	300	0.12	0.53	0
	5	2.00	2.00	100	0.53	0.58	66
	6	2.00	2.00	595	0.58	1.42	0
	7	2.00	2.00	1310	1.42	1.28	1433
	8	2.00	2.00	619	1.28	2.00	0
	9	2.00	2.00	930	2.00	2.00	928
	10*	2.00	2.00	-	2.00	2.00	-
	11*	2.00	2.00	-	2.00	1.99	-
	12	2.00	2.00	13749	1.99	1.80	13747
	13	2.00	2.00	227	1.80	1.89	0
	14	2.00	2.00	211	1.89	1.97	0
	15*	2.00	2.00	-	1.97	1.94	-
	16	2.00	2.00	100	1.94	1.98	0
	17*	2.00	2.00	-	1.98	2.00	-
		Totals		33254			32050

* Main stem stages that are tributaries   ** Tributary #1 is the main stem

stream concentration. A higher allowable concentration permits greater flexibility and greater possibilities for reducing costs.

Much further work needs to be done to extend the steady state technique established in this research to the unsteady state of nature. However, regardless of the sophistication of this technique used, the low-flow condition of streams, for which this program was designed, must remain the critical factor in the design of treatment plants.

V DISCUSSION

Return flows are of vital importance to the water economy of the state because they represent a growing quantity of potentially reusable water, and because of the effect they may have on the quality of receiving waters. The definition of receiving waters must include all water downstream from the release point to some reasonable distance offshore in the Gulf. This point is well illustrated by the phosphate concentration estimated to exist at the present time in San Antonio Bay. The high estimated concentration is derived mainly from well-treated municipal effluent originating about 150 miles upstream. Another point illustrated by the present phosphate concentration in San Antonio Bay is that the effect of return flow on any particular receiving water depends more on the relationship of the quantity of return flow to the quantity of receiving water available for dilution than on the absolute quantity of return flow. Evaluations made on the basis of drainage basins are therefore more meaningful than are those made on a statewide basis.

The potential effect of return flows on future water quality makes a knowledge of the location, quality, and quantity of returnflow essential to the development of quality management plans. Concepts used and refined in this research provide a rational method of evaluating return flows. If the concepts used are valid, a step has been taken toward the development of input data for more complete systems analyses of the total water resource quality management problem.

Evaluation of the degree of accuracy of results obtained in this research would require many years of data collection and analysis and the expenditure of large sums of money. Because such expenditures of time and money are not justifiable for determining the efficacy of the concepts used, a logical discussion of the validity of the major concepts used is in order.

Validity of Methodology

Projection Technique: The technique used in projecting water requirements is a rational approach in that it assumes that people will migrate to areas where employment opportunities exist and away from areas where there are limited employment opportunities as a result of resource development. That is, it relates population changes to economic as well as biological factors. The logic of the method is unassailable, but an obvious defect in the method is the impossibility of completely evaluating the resources available in even a limited area. Climatic and other somewhat intangible resources must be included in the evaluation along with the more obvious resources such as mineral deposits. Thus, projections made by this method can be expected to be good indicators of trends on a short term basis, but as with all other forecasting techniques, long-range projections are likely to be less accurate. Inaccuracies of input data will tend to magnify errors in long range projections to the extent that they may become practically meaningless unless they are updated periodically.

The purpose of making projections is to allow time for orderly planning and development of facilities to meet approaching problems before they become crises. The technique used fulfills this purpose by providing good short term estimates and reasonable long-range indications of future needs.

Return Flow Quantity Estimation: That return flows are related to water usage is self-evident. The method used in evaluating municipal S/W ratios is essentially a straightforward mathematical means for separating municipal wastewater from other water that enters the sanitary sewer system largely as a result of precipitation, and for determining the fraction of total municipal water use that is consumptive use.

Many factors other than precipitation influence the S/W ratio that will prevail in a given city, but if constant economic conditions exist, these factors may remain fairly constant from year to year. For example, in any particular family, the quantity of water used for bathing, and the quantity of wastewater discharged as a result of bathing is not likely to vary radically from year to year.

The method used accounts for the effects of these constants without actually evaluating them individually. Results obtained for normal precipitation can therefore be expected to be reasonable approximations of future trends.

Industrial S/W ratios are apparently relatively independent of annual precipitation, and highly dependent on the availability of low cost water. It is therefore logical to assume that the presently existing ratios in specific areas will decline in the future as the availability of low cost water decreases. No concrete evidence is available to support this argument per se, but the fact that ratios are higher in areas of plentiful supply strongly suggests that it is well founded.

Return Flow Quality Estimation: The methods used for estimating municipal return flow quality can be expected to yield reasonably accurate results, especially for larger areas such as river basins. The assumption that pollutant concentration in return flow is the sum of pollutant concentration in the water supply and pollutant concentration added by water users is certainly correct except for the effect of infiltration to the sewer system. The assumption that the same concentration is added by all cities can be expected to yield reasonable overall results, but to be inaccurate for many individual cities. Thus, from the standpoint of basin wide water resources management, the results should be reasonable approximations of actual conditions.

The method used in estimating industrial return flow quality may give a reasonable approximation of the worst conditions that may occur, but results are probably not indicative of average conditions. If permits are revised in the future to apply more stringent standards, the quality data reported on them should become increasingly abundant and reliable.

Estimation of Return Flow Effects: Models used in estimating gross effects of return flows include many simplifications of complex phenomena. Results obtained should be considered no more than indications of actual results that would be obtained if all the required input data were available. Mixing and exchange relationships used in the model need to be made more representative of field conditions before concrete conclusions can be drawn. It is well to note, however, that the models as used yield results that are in general agreement with known field conditions.

Optimization Technique: The optimization technique used is merely an application of well-known dynamic programming techniques to the maintenance of stream standards. As such it requires no justification. Results obtained by the method can be expected to reflect the degree of accuracy of input data and cost functions used. Savings made possible by use of the method will be dependent on the stream standards that are established.

Management Responsibilities

Municipal and industrial return flows are a significant and growing fraction of the total water resources in Texas. Detailed knowledge of the quantity, quality, and location of these return flows is essential to the development of quality management plans. Presently available data are generally inadequate except for the quantities of municipal return flows and their concentrations of suspended solids and 5-day BOD. Available data are located in several different state agencies and a lack of consistency among agencies in data processing practices is readily apparent.

Local solutions to water resource problems are not generally adequate now, and they will become less adequate in the future because the factors that influence the availability and quality of water transcend local artificial political boundaries. Conditions that adversely affect the quality of a stream may persist for hundreds of miles downstream.

More stringent data reporting regulations should be adopted for both municipal and industrial water use and return flow, and a Central Data Processing and Evaluation Center should be established to receive and process all data related to water quality, water use, and return flow.

APPENDIX A

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS (MGY)

APPENDIX A

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
FORT WORTH	MUN	30670	42127	55502	70058	88510	111910	141595
FORT WORTH	IND	9640	10421	11480	12868	14442	16227	18256
FORT WORTH	TOT	40311	52548	66982	82926	102952	128138	159851
DALLAS	MUN	62444	98761	137694	169234	208065	255895	314846
DALLAS	IND	24264	27932	31392	34437	37780	41450	45479
DALLAS	TOT	86708	126693	169085	203671	245845	297345	360325
TYLER	MUN	4983	7924	11562	15413	20628	27713	37361
TYLER	IND	5075	6807	8365	9280	10347	11598	13068
TYLER	TOT	10059	14731	19927	24692	30976	39311	50429
LONGVIEW MARSHAL	MUN	6140	8244	11010	14426	18928	24869	32718
LONGVIEW MARSHAL	IND	8249	12603	17696	22469	28579	36416	46483
LONGVIEW MARSHAL	TOT	14389	20847	28706	36895	47507	61284	79201
WACO	MUN	12680	19155	26258	32529	40427	50398	63018
WACO	IND	6836	7992	9355	10967	12893	15196	17952
WACO	TOT	19516	27147	35613	43497	53321	65595	80970
PALESTINE	MUN	1376	1899	2489	3075	3808	4726	5875
PALESTINE	IND	166	197	227	253	282	314	350
PALESTINE	TOT	1542	2097	2715	3328	4090	5040	6225
LUFKIN	MUN	1561	2403	3357	4239	5360	6787	8607
LUFKIN	IND	6897	8764	10947	13449	16526	20313	24973
LUFKIN	TOT	8458	11167	14305	17687	21886	27100	33580
MIDDLE SABINE	MUN	758	1046	1368	1684	2073	2552	3144
MIDDLE SABINE	IND	787	1024	1201	1265	1335	1410	1493
MIDDLE SABINE	TOT	1545	2070	2569	2949	3407	3963	4637
AUSTIN	MUN	15414	23167	32461	42029	54479	70691	91814
AUSTIN	IND	2346	4089	6029	6756	7572	8487	9515
AUSTIN	TOT	17759	27256	38490	48785	62051	79178	101329
BRYAN	MUN	3480	5041	6791	8508	10694	13483	17046
BRYAN	IND	65	87	107	119	133	149	167
BRYAN	TOT	3545	5128	6898	8627	10827	13632	17213
HOUSTON	MUN	78663	112869	153394	197443	254151	327158	421160
HOUSTON	IND	154897	248763	347627	422156	512724	622788	756561
HOUSTON	TOT	233559	361632	501021	619599	766874	949945	1177721

APPENDIX A, CONTINUED

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
LOWER SABINE	MUN	9809	14571	20493	27259	36264	48251	64209
LOWER SABINE	IND	79020	151920	245828	312597	399039	511033	656235
LOWER SABINE	TOT	88828	166491	266321	339856	435304	559285	720444
SAN ANTONIO	MUN	9298	11731	14314	16872	19953	23679	28202
SAN ANTONIO	IND	10278	14258	18124	20932	24212	28045	32526
SAN ANTONIO	TOT	19576	25989	32438	37804	44165	51723	60728
VICTORIA	MUN	2480	4086	5928	7515	9534	12106	15384
VICTORIA	IND	20522	35152	51495	63326	77981	96153	118709
VICTORIA	TOT	23002	39238	57423	70841	87516	108260	134093
CORPUS CHRISTI	MUN	14909	20549	27848	37135	49699	66729	89856
CORPUS CHRISTI	IND	18234	29770	41477	48993	57909	68490	81050
CORPUS CHRISTI	TOT	33143	50319	69325	86128	107608	135219	170906
LOWER VALLEY	MUN	22852	28475	34365	40129	46884	54805	64103
LOWER VALLEY	IND	4318	4777	5277	5811	6400	7048	7762
LOWER VALLEY	TOT	27170	33252	39642	45940	53283	61853	71866
LAREDO	MUN	3449	4429	5469	6493	7713	9167	10899
LAREDO	IND	214	302	383	434	493	559	635
LAREDO	TOT	3662	4731	5852	6928	8206	9726	11533
DEL RIO	MUN	1921	2371	2865	3375	3990	4734	5634
DEL RIO	IND	52	48	48	54	60	67	74
DEL RIO	TOT	1973	2419	2913	3428	4050	4801	5709
BROWNWOOD	MUN	2053	2785	3477	4000	4606	5308	6125
BROWNWOOD	IND	659	815	978	1130	1307	1510	1746
BROWNWOOD	TOT	2712	3600	4456	5131	5912	6819	7870
SAN ANGELO	MUN	4568	6145	7867	9578	11677	14254	17421
SAN ANGELO	IND	728	875	1021	1128	1247	1379	1525
SAN ANGELO	TOT	5296	7019	8888	10706	12923	15632	18946
ABILENE	MUN	7220	9621	12013	14003	16336	19073	22285
ABILENE	IND	1964	2496	3125	3355	3606	3879	4175
ABILENE	TOT	9184	12117	15138	17358	19942	22951	26460
BIG SPRING	MUN	3024	4619	6192	7150	8257	9535	11012
BIG SPRING	IND	4427	5288	6060	6659	7322	8054	8865
BIG SPRING	TOT	7451	9907	12252	13810	15578	17589	19877

APPENDIX A, CONTINUED

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
MIDLAND ODESSA	MUN	10339	13848	17297	20081	23330	27124	31559
MIDLAND ODESSA	IND	5735	8507	11676	13739	16234	19258	22932
MIDLAND ODESSA	TOT	16074	22355	28973	33821	39564	46381	54491
EL PASO	MUN	20826	27188	34580	42850	53109	65839	81637
EL PASO	IND	4414	5880	7333	8563	10009	11708	13705
EL PASO	TOT	25240	33067	41913	51414	63118	77547	95343
LUBBOCK	MUN	13439	19153	24923	29522	35035	41654	49610
LUBBOCK	IND	7064	8479	9917	10965	12191	13647	15401
LUBBOCK	TOT	20503	27632	34840	40487	47227	55300	65011
AMARILLO	MUN	15465	24757	33788	38700	44360	50886	58416
AMARILLO	IND	28598	42573	55503	60943	66945	73572	80895
AMARILLO	TOT	44062	67330	89291	99643	111305	124458	139312
WICHITA FALLS	MUN	8317	11023	13759	16101	18855	22097	25913
WICHITA FALLS	IND	1786	2190	2564	2798	3053	3331	3635
WICHITA FALLS	TOT	10104	13213	16323	18898	21908	25428	29548
GAINESVILLE	MUN	733	1083	1456	1779	2175	2658	3249
GAINESVILLE	IND	79	84	90	99	109	120	132
GAINESVILLE	TOT	812	1167	1546	1879	2284	2778	3381
SHERMAN DENISON	MUN	2729	3712	4860	6112	7690	9677	12182
SHERMAN DENISON	IND	2492	3312	4103	4547	5071	5689	6421
SHERMAN DENISON	TOT	5222	7024	8962	10659	12760	15366	18603
PARIS	MUN	1095	1757	2440	2901	3449	4103	4882
PARIS	IND	2613	6883	12368	14312	16568	19188	22232
PARIS	TOT	3708	8640	14808	17212	20017	23291	27114
SULFUR SPRINGS	MUN	326	547	828	1128	1536	2092	2850
SULFUR SPRINGS	IND	60	73	82	86	91	95	100
SULFUR SPRINGS	TOT	385	620	910	1214	1627	2188	2950
NORTHEAST TEXAS	MUN	3419	4504	5757	7030	8605	10557	12982
NORTHEAST TEXAS	IND	17637	22570	26134	27316	28560	29870	31251
NORTHEAST TEXAS	TOT	21056	27073	31891	34345	37165	40427	44233
STATE TOTAL . .	MUN	376440	539591	722405	898351	1120180	1400510	1755595
STATE TOTAL . .	IND	430117	674928	948010	1141808	1381018	1677043	2044303
STATE TOTAL		806556	1214519	1670415	2040159	2501198	3077553	3799898

APPENDIX B

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

APPENDIX B

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
FORT WORTH	MUN	22083	29629	38111	46939	57827	71249	87789
FORT WORTH	IND	7327	7547	7924	8465	9053	9695	10394
FORT WORTH	TOT	29409	37177	46035	55404	66880	80944	98183
DALLAS	MUN	43711	66005	87665	102387	119290	138610	160571
DALLAS	IND	6794	7453	7983	8346	8726	9123	9540
DALLAS	TOT	50505	73458	95648	110732	128016	147733	170111
TYLER	MUN	3588	5481	7670	9787	12515	16027	20549
TYLER	IND	1320	1687	1975	2088	2219	2370	2545
TYLER	TOT	4908	7168	9645	11875	14734	18398	23094
LONGVIEW MARSHAL	MUN	4298	5771	7707	10098	13249	17408	22903
LONGVIEW MARSHAL	IND	2722	3963	5304	6418	7779	9446	11491
LONGVIEW MARSHAL	TOT	7020	9734	13011	16516	21029	26854	34394
WACO	MUN	8242	12291	16630	20331	24930	30659	37811
WACO	IND	1436	1678	1965	2303	2708	3191	3770
WACO	TOT	9678	13969	18594	22634	27638	33850	41581
PALESTINE	MUN	895	1235	1618	1999	2475	3072	3819
PALESTINE	IND	111	126	138	147	156	165	176
PALESTINE	TOT	1006	1361	1756	2146	2631	3237	3994
LUFKIN	MUN	858	1274	1712	2077	2519	3054	3701
LUFKIN	IND	5449	6598	7855	9196	10769	12614	14779
LUFKIN	TOT	6307	7871	9567	11273	13288	15668	18480
MIDDLE SABINE	MUN	568	785	1026	1263	1555	1914	2358
MIDDLE SABINE	IND	354	439	491	493	495	499	503
MIDDLE SABINE	TOT	923	1224	1517	1755	2050	2413	2862
AUSTIN	MUN	7861	11275	15040	18493	22700	27805	33971
AUSTIN	IND	1994	3312	4654	4970	5309	5671	6059
AUSTIN	TOT	9855	14587	19695	23463	28008	33476	40030
BRYAN	MUN	1705	2453	3282	4084	5098	6382	8012
BRYAN	IND	25	32	38	40	43	46	49
BRYAN	TOT	1731	2485	3320	4124	5140	6428	8060
HOUSTON	MUN	53491	75623	101240	128338	162656	206110	261119
HOUSTON	IND	102232	156467	208374	241155	279125	323108	374063
HOUSTON	TOT	155722	232089	309614	369493	441781	529218	635183

APPENDIX B, CONTINUED

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
LOWER SABINE	MUN	8435	12434	17351	22898	30220	39888	52652
LOWER SABINE	IND	60055	110032	169680	205626	250150	305300	373620
LOWER SABINE	TOT	68490	122467	187031	228523	280371	345188	426272
SAN ANTONIO	MUN	6788	8290	9781	11136	12704	14523	16639
SAN ANTONIO	IND	3906	5163	6255	6885	7589	8377	9259
SAN ANTONIO	TOT	10693	13453	16036	18020	20293	22900	25898
VICTORIA	MUN	1240	1975	2766	3382	4132	5044	6153
VICTORIA	IND	19496	31825	44430	52069	61106	71805	84482
VICTORIA	TOT	20736	33800	47196	55451	65238	76849	90636
CORPUS CHRISTI	MUN	6560	8733	11417	14668	18886	24356	31450
CORPUS CHRISTI	IND	6017	9362	12431	13993	15763	17767	20037
CORPUS CHRISTI	TOT	12577	18096	23849	28662	34648	42123	51486
LOWER VALLEY	MUN	8455	10488	12600	14647	17034	19821	23077
LOWER VALLEY	IND	3454	3642	3834	4024	4223	4432	4652
LOWER VALLEY	TOT	11910	14130	16435	18671	21257	24253	27729
LAREDO	MUN	1552	1956	2370	2760	3214	3743	4359
LAREDO	IND	24	33	42	48	54	62	70
LAREDO	TOT	1575	1989	2412	2807	3268	3805	4429
DEL RIO	MUN	672	810	955	1097	1263	1460	1690
DEL RIO	IND	17	14	14	15	16	17	18
DEL RIO	TOT	689	825	969	1112	1279	1476	1708
BROWNWOOD	MUN	924	1244	1542	1760	2011	2300	2634
BROWNWOOD	IND	652	769	880	969	1067	1175	1295
BROWNWOOD	TOT	1576	2013	2421	2729	3078	3476	3928
SAN ANGELO	MUN	2055	2714	3409	4071	4865	5820	6968
SAN ANGELO	IND	371	425	473	498	524	553	583
SAN ANGELO	TOT	2427	3139	3882	4568	5390	6373	7551
ABILENE	MUN	3826	4971	6047	6861	7787	8837	10028
ABILENE	IND	1100	1332	1589	1626	1666	1707	1751
ABILENE	TOT	4927	6303	7636	8488	9452	10544	11780
BIG SPRING	MUN	1351	2079	2725	3075	3468	3909	4405
BIG SPRING	IND	1063	1269	1454	1598	1757	1933	2128
BIG SPRING	TOT	2454	3348	4179	4673	5225	5842	6533

APPENDIX B, CONTINUED

SUMMARY OF PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

TRADE AREA		1960	1970	1980	1990	2000	2010	2020
MIDLAND ODESSA	MUN	4756	6231	7611	8635	9799	11121	12624
MIDLAND ODESSA	IND	2007	2838	3711	4162	4687	5298	6013
MIDLAND ODESSA	TOT	6763	9069	11322	12797	14485	16419	18636
EL PASO	MUN	6456	8383	10605	13069	16110	19861	24491
EL PASO	IND	1677	2129	2531	2817	3137	3497	3902
EL PASO	TOT	8134	10512	13135	15886	19247	23359	28393
LUBBOCK	MUN	7123	9832	12378	14171	16233	18605	21332
LUBBOCK	IND	2472	2828	3152	3322	3520	3755	4038
LUBBOCK	TOT	9595	12660	15531	17492	19753	22360	25370
AMARILLO	MUN	7114	11141	14867	16641	18631	20863	23367
AMARILLO	IND	14013	19880	24700	25846	27057	28338	29695
AMARILLO	TOT	21127	31021	39567	42487	45689	49202	53061
WICHITA FALLS	MUN	3576	4685	5779	6682	7731	8949	10365
WICHITA FALLS	IND	893	1044	1164	1211	1259	1309	1362
WICHITA FALLS	TOT	4470	5729	6943	7893	8990	10258	11727
GAINESVILLE	MUN	476	695	922	1112	1341	1617	1949
GAINESVILLE	IND	42	42	43	46	48	50	52
GAINESVILLE	TOT	518	737	966	1158	1389	1667	2002
SHERMAN DENISON	MUN	1774	2382	3078	3820	4742	5887	7309
SHERMAN DENISON	IND	548	729	903	1000	1116	1251	1413
SHERMAN DENISON	TOT	2322	3110	3980	4820	5857	7138	8722
PARIS	MUN	701	1113	1529	1798	2115	2489	2929
PARIS	IND	601	1583	2845	3292	3811	4413	5113
PARIS	TOT	1302	2696	4374	5090	5926	6902	8043
SULFUR SPRINGS	MUN	260	429	635	846	1126	1500	1995
SULFUR SPRINGS	IND	43	50	54	54	54	54	54
SULFUR SPRINGS	TOT	304	478	688	899	1180	1553	2049
NORTHEAST TEXAS	MUN	2564	3340	4222	5097	6167	7478	9087
NORTHEAST TEXAS	IND	11993	14626	16140	16077	16019	15966	15919
NORTHEAST TEXAS	TOT	14557	17966	20361	21173	22186	23445	25007
STATE TOTAL . .	MUN	224000	315745	414290	504019	614393	750363	918108
STATE TOTAL . .	IND	260208	398920	543024	628796	731003	852990	998823
STATE TOTAL		484208	714666	957314	1132815	1345396	1603353	1916931

APPENDIX C

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT BURDEN OF POLLUTANTS IN STREAMS

APPENDIX C

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 1 FORT WORTH

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	29	22	17	14	11	9	7
SUS SOL	35	26	20	16	13	11	9
TOT SOL	533	397	309	251	204	165	134
CHLORIDE	111	83	65	52	43	35	28
NITRATES	24	18	14	11	9	7	6
PHOSPHATES	26	20	15	12	10	8	7
INDUSTRIAL							
BOD	2	2	2	2	2	2	1
SUS SOL	437	424	404	378	354	330	308
TOT SOL	6613	6419	6114	5724	5352	4998	4661
CHLORIDE	133	129	123	115	108	101	94
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	6130	5951	5668	5306	4961	4633	4321

TRADING AREA NUMBER 2 DALLAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	36	24	18	15	13	11	10
SUS SOL	45	30	23	19	17	14	12
TOT SOL	681	451	340	291	250	215	185
CHLORIDE	144	95	72	61	53	45	39
NITRATES	25	16	12	11	9	8	7
PHOSPHATES	27	18	14	12	10	9	7
INDUSTRIAL							
BOD	1198	1092	1019	975	933	892	853
SUS SOL	226	206	193	184	176	168	161
TOT SOL	2920	2662	2485	2377	2274	2175	2080
CHLORIDE	10	9	9	8	8	8	7
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	77	70	66	63	60	57	55

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 3 TYLER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	34	22	16	12	10	8	6
SUS SOL	42	28	20	15	12	9	7
TOT SOL	464	304	217	170	133	104	81
CHLORIDE	106	69	49	39	30	24	18
NITRATES	25	16	12	9	7	6	4
PHOSPHATES	27	18	13	10	8	6	5
INDUSTRIAL							
BOD	235	184	157	148	140	131	122
SUS SOL	786	615	525	497	467	437	407
TOT SOL	953	745	636	602	566	530	494
CHLORIDE	83	65	55	52	49	46	43
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	167	131	111	105	99	93	86

TRADING AREA NUMBER 4 LONGVIEW MARSHAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	7	5	4	3	2	2	1
SUS SOL	28	21	16	12	9	7	5
TOT SOL	379	282	211	161	123	94	71
CHLORIDE	114	85	63	48	37	28	21
NITRATES	25	19	14	11	8	6	5
PHOSPHATES	26	20	15	11	9	6	5
INDUSTRIAL							
BOD	142	98	73	60	50	41	34
SUS SOL	608	417	312	258	213	175	144
TOT SOL	2543	1747	1305	1079	890	733	602
CHLORIDE	993	682	510	421	347	286	235
COD	369	254	190	157	129	106	88
SULFATES	725	498	372	308	254	209	172

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 5 WACO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	45	30	22	18	15	12	10
SUS SOL	43	29	21	17	14	12	9
TOT SOL	724	485	359	293	239	195	158
CHLORIDE	156	104	77	63	51	42	34
NITRATES	27	18	13	11	9	7	6
PHOSPHATES	27	18	13	11	9	7	6
INDUSTRIAL							
BOD	13	11	9	8	7	6	5
SUS SOL	9673	8274	7069	6029	5129	4351	3683
TOT SOL	786	672	574	490	417	354	299
CHLORIDE	79	67	57	49	42	35	30
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	156	134	114	97	83	70	59

TRADING AREA NUMBER 6 PALESTINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	76	55	42	34	27	22	18
SUS SOL	69	50	38	31	25	20	16
TOT SOL	617	447	341	276	223	180	145
CHLORIDE	128	93	71	57	46	37	30
NITRATES	24	18	13	11	9	7	6
PHOSPHATES	26	19	15	12	10	8	6
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	3114	2750	2509	2362	2224	2095	1972
TOT SOL	10379	9168	8365	7875	7415	6984	6575
CHLORIDE	3114	2750	2509	2362	2224	2095	1972
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	156	138	125	118	111	105	99

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 7 LUFKIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	48	33	24	20	16	14	11
SUS SOL	69	46	34	28	23	19	16
TOT SOL	592	399	297	245	202	166	137
CHLORIDE	109	74	55	45	37	31	25
NITRATES	25	17	12	10	8	7	6
PHOSPHATES	27	18	14	11	9	8	6
INDUSTRIAL							
BOD	371	306	257	220	188	160	137
SUS SOL	37	31	26	22	19	16	14
TOT SOL	3176	2623	2203	1882	1607	1372	1171
CHLORIDE	371	306	257	220	188	160	137
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	37	31	26	22	19	16	14

TRADING AREA NUMBER 8 MIDDLE SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	30	22	16	13	11	9	7
SUS SOL	51	37	28	23	19	15	12
TOT SOL	560	405	310	252	205	166	135
CHLORIDE	106	77	59	48	39	31	25
NITRATES	25	18	14	11	9	8	6
PHOSPHATES	26	19	15	12	10	8	6
INDUSTRIAL							
BOD	10	8	7	7	7	7	7
SUS SOL	23	19	17	17	17	17	17
TOT SOL	5939	4791	4289	4270	4247	4217	4181
CHLORIDE	4913	3963	3548	3533	3513	3489	3458
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	373	301	270	268	267	265	263

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 9 AUSTIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	19	13	10	8	7	5	4
SUS SOL	32	23	17	14	11	9	7
TOT SOL	1020	711	533	433	353	288	236
CHLORIDE	160	112	84	68	56	45	37
NITRATES	29	20	15	12	10	8	7
PHOSPHATES	27	19	14	11	9	8	6
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	1686	1015	722	676	633	593	555
TOT SOL	961	578	412	385	361	338	316
CHLORIDE	41	25	17	16	15	14	13
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	41	25	17	16	15	14	13

TRADING AREA NUMBER 10 BRYAN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	26	18	13	11	9	7	5
SUS SOL	58	40	30	24	19	15	12
TOT SOL	574	399	298	240	192	153	122
CHLORIDE	123	85	64	51	41	33	26
NITRATES	25	17	13	10	8	7	5
PHOSPHATES	27	19	14	11	9	7	6
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	162	126	107	101	95	89	84
TOT SOL	3232	2522	2149	2026	1903	1786	1672
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 11 HOUSTON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	29	20	15	12	9	7	6
SUS SOL	47	33	25	19	15	12	10
TOT SOL	748	529	395	312	246	194	153
CHLORIDE	190	134	100	79	62	49	39
NITRATES	24	17	13	10	8	6	5
PHOSPHATES	27	19	14	11	9	7	5
INDUSTRIAL							
BOD	214	139	105	91	79	67	59
SUS SOL	348	227	170	148	128	110	96
TOT SOL	9023	5886	4423	3834	3332	2848	2488
CHLORIDE	8031	5239	3936	3412	2965	2535	2215
COD	933	609	457	396	345	295	257
SULFATES	1378	899	675	585	509	435	380

TRADING AREA NUMBER 12 LOWER SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	13	9	7	5	4	3	2
SUS SOL	25	17	12	9	7	5	4
TOT SOL	473	321	230	174	132	100	76
CHLORIDE	137	93	67	50	38	29	22
NITRATES	25	17	12	9	7	5	4
PHOSPHATES	27	18	13	10	8	6	4
INDUSTRIAL							
BOD	53	29	19	15	13	10	8
SUS SOL	108	59	38	31	26	21	17
TOT SOL	3529	1938	1249	1027	843	691	567
CHLORIDE	4552	2499	1612	1325	1088	892	731
COD	867	476	307	252	207	170	139
SULFATES	262	144	93	76	63	51	42

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 13 SAN ANTONIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	23	17	13	12	10	9	8
SUS SOL	21	15	12	10	9	8	7
TOT SOL	615	437	345	304	268	237	209
CHLORIDE	120	85	67	59	52	46	41
NITRATES	30	21	17	15	13	12	10
PHOSPHATES	27	19	15	13	12	10	9
INDUSTRIAL							
BOD	103	78	64	59	53	48	44
SUS SOL	3000	2269	1873	1702	1544	1399	1265
TOT SOL	4606	3484	2876	2613	2370	2147	1943
CHLORIDE	694	525	433	394	357	323	293
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	583	441	364	331	300	272	246

TRADING AREA NUMBER 14 VICTORIA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	21	13	9	8	6	5	4
SUS SOL	29	18	13	11	9	7	6
TOT SOL	798	501	358	293	239	196	161
CHLORIDE	285	179	128	105	86	70	57
NITRATES	25	16	11	9	8	6	5
PHOSPHATES	28	17	12	10	8	7	6
INDUSTRIAL							
BOD	41	25	18	15	13	11	9
SUS SOL	131	80	57	49	42	36	30
TOT SOL	3474	2128	1524	1301	1108	943	802
CHLORIDE	993	608	436	372	317	270	229
COD	405	248	178	152	129	110	94
SULFATES	22	13	10	8	7	6	5

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 15 CORPUS CHRISTI

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	19	14	11	8	6	5	4
SUS SOL	53	40	31	24	19	14	11
TOT SOL	855	643	491	383	297	230	178
CHLORIDE	273	205	157	122	95	74	57
NITRATES	25	19	14	11	9	7	5
PHOSPHATES	26	20	15	12	9	7	5
INDUSTRIAL							
BOD	357	233	173	151	137	121	106
SUS SOL	454	296	219	192	175	153	135
TOT SOL	3501	2282	1693	1483	1347	1183	1040
CHLORIDE	1535	1001	742	650	591	519	456
COD	371	242	179	157	143	125	110
SULFATES	1544	1007	747	654	594	522	458

TRADING AREA NUMBER 16 LOWER VALLEY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	34	28	23	20	17	15	13
SUS SOL	77	62	52	44	38	33	28
TOT SOL	1087	876	729	628	540	464	398
CHLORIDE	275	222	185	159	137	117	101
NITRATES	25	20	16	14	12	10	9
PHOSPHATES	26	21	17	15	13	11	9
INDUSTRIAL							
BOD	2	2	2	2	2	2	2
SUS SOL	36	34	32	31	29	28	26
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	3045	2897	2730	2623	2491	2369	2258
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 17 LAREDO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	101	80	66	57	49	42	36
SUS SOL	54	43	35	30	26	22	19
TOT SOL	841	668	551	473	406	349	300
CHLORIDE	190	151	124	107	92	79	68
NITRATES	29	23	19	16	14	12	10
PHOSPHATES	26	20	17	14	12	11	9
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	3328	2355	1857	1636	1443	1272	1120
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	8319	5889	4644	4090	3607	3179	2801

TRADING AREA NUMBER 18 DEL RIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2	2	1	1	1	1	1
SUS SOL	5	4	4	3	3	2	2
TOT SOL	522	434	368	320	278	241	208
CHLORIDE	94	78	66	58	50	43	37
NITRATES	32	26	22	19	17	15	13
PHOSPHATES	25	21	18	16	14	12	10
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	34	38	40	38	36	33	31
TOT SOL	2881	3298	3416	3231	3046	2846	2687
CHLORIDE	805	921	954	903	851	795	750
COD	144	165	171	162	152	142	134
SULFATES	668	765	792	750	707	660	623

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 19 BROWNWOOD

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	37	28	22	20	17	15	13
SUS SOL	39	29	24	21	18	16	14
TOT SOL	461	343	277	242	212	185	162
CHLORIDE	120	89	72	63	55	48	42
NITRATES	25	19	15	13	12	10	9
PHOSPHATES	26	19	16	14	12	11	9
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	1691	1433	1254	1138	1033	938	852
TOT SOL	8407	7126	6234	5660	5139	4665	4235
CHLORIDE	871	738	646	587	532	483	439
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	743	630	551	500	454	412	374

TRADING AREA NUMBER 20 SAN ANGELO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	54	41	33	27	23	19	16
SUS SOL	46	35	28	23	19	16	13
TOT SOL	695	526	419	351	293	245	205
CHLORIDE	196	148	118	99	83	69	58
NITRATES	25	19	15	13	11	9	7
PHOSPHATES	26	20	16	13	11	9	8
INDUSTRIAL							
BOD	14	12	11	10	10	9	9
SUS SOL	36	32	29	27	26	24	23
TOT SOL	781	682	614	583	553	525	498
CHLORIDE	364	318	286	272	258	245	232
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 21 ABILENE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	26	20	16	14	13	11	10
SUS SOL	37	28	23	21	18	16	14
TOT SOL	552	425	349	308	271	239	210
CHLORIDE	125	97	79	70	62	54	48
NITRATES	25	19	16	14	12	11	9
PHOSPHATES	26	20	16	14	13	11	10
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	37	31	26	25	24	24	23
TOT SOL	6700	5533	4638	4532	4425	4317	4208
CHLORIDE	166	137	115	112	110	107	104
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	3177	2624	2200	2149	2098	2047	1996

TRADING AREA NUMBER 22 BIG SPRING

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	67	45	34	30	27	24	21
SUS SOL	41	27	21	18	16	14	13
TOT SOL	583	390	298	264	234	208	184
CHLORIDE	120	80	61	54	48	43	38
NITRATES	25	17	13	11	10	9	8
PHOSPHATES	27	18	14	12	11	10	9
INDUSTRIAL							
BOD	37	31	27	25	22	20	18
SUS SOL	267	223	195	177	161	147	133
TOT SOL	4609	3859	3367	3064	2787	2533	2302
CHLORIDE	407	341	297	271	246	224	203
COD	79	66	58	53	48	43	40
SULFATES	364	305	266	242	220	200	182

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 23 MIDLAND ODESSA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	24	18	15	13	12	10	9
SUS SOL	55	42	35	30	27	24	21
TOT SOL	1038	792	649	572	504	444	391
CHLORIDE	213	162	133	117	103	91	80
NITRATES	34	26	21	19	16	14	13
PHOSPHATES	26	20	16	14	13	11	10
INDUSTRIAL							
BOD	29	20	16	14	12	11	10
SUS SOL	8644	6114	4675	4168	3702	3274	2885
TOT SOL	9262	6551	5009	4466	3966	3509	3092
CHLORIDE	3265	2310	1766	1575	1398	1237	1090
COD	83	59	45	40	36	32	28
SULFATES	713	505	386	344	306	270	238

TRADING AREA NUMBER 24 EL PASO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	48	37	29	24	19	15	13
SUS SOL	40	31	24	20	16	13	11
TOT SOL	738	568	449	364	296	240	194
CHLORIDE	173	133	105	85	69	56	46
NITRATES	25	19	15	12	10	8	7
PHOSPHATES	26	20	16	13	10	8	7
INDUSTRIAL							
BOD	31	25	21	19	17	15	13
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	8328	6561	5520	4960	4453	3994	3581
CHLORIDE	487	383	323	290	260	233	209
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1085	855	719	646	580	520	466

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 25 LUBBOCK

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	105	76	60	53	46	40	35
SUS SOL	113	82	65	57	50	43	38
TOT SOL	930	674	535	467	408	356	310
CHLORIDE	167	121	96	84	73	64	56
NITRATES	33	24	19	17	14	13	11
PHOSPHATES	26	19	15	13	12	10	9
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	36	32	29	27	26	24	22
TOT SOL	781	683	612	581	549	514	478
CHLORIDE	156	137	122	116	110	103	96
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	156	137	122	116	110	103	96

TRADING AREA NUMBER 26 AMARILLO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	80	51	38	34	31	27	24
SUS SOL	71	45	34	30	27	24	22
TOT SOL	690	441	330	295	263	235	210
CHLORIDE	114	73	55	49	44	39	35
NITRATES	31	20	15	13	12	11	9
PHOSPHATES	27	18	13	12	10	9	8
INDUSTRIAL							
BOD	535	377	304	290	277	265	253
SUS SOL	22	16	13	12	12	11	10
TOT SOL	3297	2324	1871	1788	1708	1631	1556
CHLORIDE	576	406	327	313	299	285	272
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	4087	2881	2319	2216	2117	2021	1929

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 27 WICHITA FALLS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	54	41	34	29	25	22	19
SUS SOL	80	61	50	43	37	32	28
TOT SOL	541	413	335	290	250	216	187
CHLORIDE	120	92	74	64	56	48	42
NITRATES	33	25	20	17	15	13	11
PHOSPHATES	26	20	16	14	12	10	9
INDUSTRIAL							
BOD	396	339	304	292	281	270	260
SUS SOL	456	390	350	336	323	311	299
TOT SOL	3125	2674	2397	2305	2217	2131	2050
CHLORIDE	1494	1279	1146	1102	1060	1019	980
COD	157	135	121	116	111	107	103
SULFATES	322	275	247	237	228	219	211

TRADING AREA NUMBER 28 GAINESVILLE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	46	31	24	20	16	14	11
SUS SOL	46	31	24	20	16	14	11
TOT SOL	709	486	366	304	252	209	173
CHLORIDE	112	77	58	48	40	33	27
NITRATES	26	18	13	11	9	8	6
PHOSPHATES	27	18	14	12	10	8	7
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 29 SHERMAN DENISON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	42	31	24	19	16	13	10
SUS SOL	52	39	30	24	20	16	13
TOT SOL	953	710	549	442	356	287	231
CHLORIDE	225	168	130	105	84	68	55
NITRATES	25	19	14	12	9	8	6
PHOSPHATES	26	20	15	12	10	8	6
INDUSTRIAL							
BOD	81	61	49	44	40	35	31
SUS SOL	82	61	50	45	40	36	32
TOT SOL	3267	2459	1985	1791	1606	1431	1268
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	6534	4918	3969	3581	3212	2863	2536
SULFATES	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 30 PARIS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	54	34	25	21	18	15	13
SUS SOL	20	12	9	8	6	5	5
TOT SOL	541	341	248	211	179	152	129
CHLORIDE	121	76	55	47	40	34	29
NITRATES	25	16	12	10	8	7	6
PHOSPHATES	28	17	13	11	9	8	7
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	4012	1523	848	732	633	546	471
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	13	5	3	2	2	2	2

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 31 SULFUR SPRINGS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	26	16	10	8	6	4	3
SUS SOL	35	21	14	11	8	6	5
TOT SOL	334	203	137	103	77	58	44
CHLORIDE	94	57	39	29	22	16	12
NITRATES	26	16	10	8	6	4	3
PHOSPHATES	28	17	11	9	6	5	4
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	182	157	146	146	146	145	145
CHLORIDE	78	68	63	63	63	63	63
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 32 NORTHEAST TEXAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	57	44	35	29	24	20	16
SUS SOL	38	29	23	19	16	13	11
TOT SOL	504	387	306	254	210	173	142
CHLORIDE	126	96	76	63	52	43	35
NITRATES	25	19	15	13	10	9	7
PHOSPHATES	26	20	16	13	11	9	7
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	3184	2611	2366	2375	2384	2392	2399
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX C, CONTINUED

MUNICIPAL AND INDUSTRIAL TREATMENT PLANT EFFLUENT QUALITY REQUIRED TO MAINTAIN PRESENT WASTE LOADS IN STREAMS (MG/L)

TRADING AREA NUMBER 33 STATE TOTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	35	25	19	15	13	11	9
SUS SOL	45	31	24	20	16	14	11
TOT SOL	699	494	377	312	258	212	175
CHLORIDE	158	111	85	70	58	48	39
NITRATES	26	19	14	12	10	8	7
PHOSPHATES	27	19	14	12	10	8	7
INDUSTRIAL							
BOD	182	119	87	75	65	55	47
SUS SOL	400	261	192	165	142	122	104
TOT SOL	5552	3622	2661	2298	1976	1694	1446
CHLORIDE	4625	3017	2216	1914	1646	1411	1205
COD	625	408	299	259	222	191	163
SULFATES	1086	709	521	450	387	331	283

APPENDIX D

QUANTITIES OF POLLUTANTS (IN THOUSANDS OF POUNDS PER YEAR) CONTRIBUTED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED

APPENDIX D

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 1 FORT WORTH

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4973	6672	8582	10570	13021	16044	19768
SUS SOL	5893	7907	10171	12527	15433	19015	23429
TOT SOL	89874	120589	155111	191038	235350	289979	357294
CHLORIDE	18785	25205	32421	39930	49192	60610	74680
NITRATES	4052	5436	6993	8612	10610	13073	16108
PHOSPHATES	4420	5931	7628	9395	11575	14261	17572
INDUSTRIAL							
BOD	122	126	132	141	151	162	173
SUS SOL	26458	27256	28614	30568	32693	35009	37534
TOT SOL	400480	412549	433112	462684	494857	529910	568129
CHLORIDE	8066	8309	8723	9319	9967	10673	11442
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	371272	382461	401524	428939	458765	491263	526694

TRADING AREA NUMBER 2 DALLAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	11666	17615	23396	27325	31836	36992	42853
SUS SOL	14582	22019	29245	34156	39795	46240	53567
TOT SOL	219458	331390	440138	514050	598919	695914	806178
CHLORIDE	46298	69911	92853	108446	126350	146813	170074
NITRATES	8020	12111	16085	18786	21887	25432	29462
PHOSPHATES	8749	13212	17547	20494	23877	27744	32140
INDUSTRIAL							
BOD	66010	72418	77562	81088	84779	88642	92688
SUS SOL	12465	13675	14647	15313	16010	16739	17503
TOT SOL	160918	176538	189077	197673	206671	216088	225951
CHLORIDE	567	622	666	696	728	761	796
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	4250	4662	4993	5220	5458	5707	5967

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 3 TYLER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	898	1371	1919	2449	3131	4010	5141
SUS SOL	1107	1691	2367	3020	3862	4946	6341
TOT SOL	12239	18696	26162	33384	42688	54670	70093
CHLORIDE	2783	4251	5949	7591	9706	12431	15938
NITRATES	658	1006	1407	1796	2296	2941	3770
PHOSPHATES	718	1097	1535	1959	2505	3208	4113
INDUSTRIAL							
BOD	2399	3066	3591	3797	4035	4310	4628
SUS SOL	8034	10268	12025	12714	13510	14431	15496
TOT SOL	9740	12449	14579	15414	16379	17496	18787
CHLORIDE	847	1083	1268	1341	1425	1522	1635
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1706	2180	2553	2700	2869	3064	3290

TRADING AREA NUMBER 4 LONGVIEW MARSHAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	215	289	386	505	663	871	1146
SUS SOL	932	1251	1671	2190	2873	3775	4966
TOT SOL	12438	16700	22304	29223	38343	50378	66279
CHLORIDE	3728	5005	6685	8759	11492	15099	19865
NITRATES	824	1107	1478	1937	2541	3339	4393
PHOSPHATES	860	1155	1543	2021	2652	3484	4584
INDUSTRIAL							
BOD	2883	4198	5618	6797	8240	10005	12171
SUS SOL	12328	17949	24019	29063	35229	42779	52039
TOT SOL	51583	75102	100499	121604	147404	178995	217739
CHLORIDE	20138	29320	39235	47475	57547	69880	85006
COD	7492	10908	14597	17663	21410	25998	31626
SULFATES	14712	21420	28663	34683	42041	51051	62102

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 5 WACO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2750	4100	5548	6782	8317	10228	12614
SUS SOL	2612	3895	5270	6443	7901	9716	11983
TOT SOL	44131	65809	89041	108857	133483	164157	202449
CHLORIDE	9486	14146	19140	23399	28693	35286	43517
NITRATES	1650	2460	3329	4069	4990	6137	7568
PHOSPHATES	1650	2460	3329	4069	4990	6137	7568
INDUSTRIAL							
BOD	144	168	197	230	271	319	377
SUS SOL	110510	129193	151224	177288	208426	245653	290200
TOT SOL	8980	10498	12288	14406	16936	19961	23581
CHLORIDE	898	1050	1229	1441	1694	1996	2358
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1784	2086	2441	2862	3365	3966	4685

TRADING AREA NUMBER 6 PALESTINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	515	710	931	1150	1424	1768	2198
SUS SOL	470	649	850	1050	1301	1614	2006
TOT SOL	4179	5766	7554	9336	11561	14346	17835
CHLORIDE	866	1194	1565	1934	2395	2972	3694
NITRATES	164	227	297	367	454	564	701
PHOSPHATES	179	247	324	400	495	615	764
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	2785	3153	3455	3670	3898	4138	4396
TOT SOL	9282	10508	11518	12235	12994	13794	14653
CHLORIDE	2785	3153	3455	3670	3898	4138	4396
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	139	158	173	184	195	207	220

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 7 LUFKIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	308	457	614	745	903	1095	1327
SUS SOL	437	648	871	1057	1282	1554	1883
TOT SOL	3766	5587	7512	9111	11050	13398	16236
CHLORIDE	694	1030	1385	1680	2038	2471	2994
NITRATES	157	234	314	381	462	560	679
PHOSPHATES	172	255	343	416	504	611	741
INDUSTRIAL							
BOD	15905	19259	22928	26842	31434	36821	43141
SUS SOL	1590	1926	2293	2684	3143	3682	4314
TOT SOL	136281	165022	196457	229997	269346	315502	369655
CHLORIDE	15905	19259	22928	26842	31434	36821	43141
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1590	1926	2293	2684	3143	3682	4314

TRADING AREA NUMBER 8 MIDDLE SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	128	177	231	284	350	431	531
SUS SOL	218	301	394	484	596	734	905
TOT SOL	2408	3325	4348	5350	6586	8110	9992
CHLORIDE	455	628	822	1011	1245	1533	1888
NITRATES	109	151	197	242	298	367	452
PHOSPHATES	114	157	205	253	311	383	472
INDUSTRIAL							
BOD	27	33	37	37	37	37	38
SUS SOL	65	81	90	90	91	92	92
TOT SOL	16453	20395	22782	22880	23005	23167	23372
CHLORIDE	13610	16871	18846	18927	19030	19165	19334
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1034	1282	1432	1438	1446	1456	1469

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 9 AUSTIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1115	1599	2132	2622	3218	3942	4816
SUS SOL	1901	2727	3638	4473	5490	6725	8216
TOT SOL	59989	86038	114775	141120	173223	212183	259238
CHLORIDE	9441	13540	18063	22209	27261	33393	40798
NITRATES	1705	2445	3261	4010	4922	6029	7366
PHOSPHATES	1573	2257	3010	3701	4544	5565	6800
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	24077	39997	56206	60023	64110	68484	73168
TOT SOL	13718	22788	32023	34198	36527	39019	41688
CHLORIDE	582	967	1359	1451	1550	1655	1769
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	582	967	1359	1451	1550	1655	1769

TRADING AREA NUMBER 10 BRYAN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	327	471	630	783	978	1224	1537
SUS SOL	740	1064	1424	1771	2211	2768	3474
TOT SOL	7324	10537	14098	17541	21895	27411	34411
CHLORIDE	1564	2251	3011	3747	4677	5855	7350
NITRATES	313	450	602	749	935	1171	1470
PHOSPHATES	341	491	657	817	1020	1277	1604
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	32	40	47	50	54	57	61
TOT SOL	631	808	948	1006	1071	1141	1218
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 11 HOUSTON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	11599	16398	21953	27829	35270	44693	56621
SUS SOL	18737	26489	35462	44954	56975	72196	91465
TOT SOL	300679	425086	569087	721408	914317	1158574	1467793
CHLORIDE	76285	107848	144383	183028	231971	293941	372393
NITRATES	9814	13875	18576	23547	29844	37817	47910
PHOSPHATES	10707	15137	20264	25688	32557	41255	52266
INDUSTRIAL							
BOD	160291	245725	327030	377287	434111	507770	581251
SUS SOL	260899	399957	532294	614095	706585	826477	946079
TOT SOL	6768030	10375361	13808334	15930342	18329649	21439783	24542409
CHLORIDE	6023701	9234307	12289730	14178366	16313803	19081893	21843300
COD	699994	1073088	1428148	1647620	1895772	2217443	2538337
SULFATES	1033365	1584144	2108302	2432297	2798631	3273497	3747216

TRADING AREA NUMBER 12 LOWER SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	844	1244	1736	2292	3024	3992	5269
SUS SOL	1548	2281	3184	4201	5545	7319	9661
TOT SOL	29618	43659	60921	80397	106108	140051	184867
CHLORIDE	8583	12652	17654	23298	30749	40585	53572
NITRATES	1548	2281	3184	4201	5545	7319	9661
PHOSPHATES	1688	2489	3473	4583	6049	7984	10539
INDUSTRIAL							
BOD	22038	40139	62244	75709	92252	112517	137263
SUS SOL	45077	82102	127318	154859	188697	230149	280765
TOT SOL	1476527	2689303	4170359	5072507	6180871	7538657	9196609
CHLORIDE	1904759	3469274	5379876	6543672	7973491	9725073	11863875
COD	362620	660467	1024199	1245758	1517961	1851421	2258597
SULFATES	109688	199782	309806	376825	459162	560029	683194

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 13 SAN ANTONIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	5329	7500	9496	10775	12217	13843	15675
SUS SOL	4821	6785	8592	9749	11054	12525	14182
TOT SOL	140828	198206	250963	284767	322880	365857	414259
CHLORIDE	27404	38570	48836	55414	62831	71194	80613
NITRATES	6851	9642	12209	13854	15708	17798	20153
PHOSPHATES	6090	8571	10852	12314	13962	15821	17914
INDUSTRIAL							
BOD	3094	4091	4956	5455	6013	6637	7336
SUS SOL	89866	118806	143923	158415	174623	192760	213050
TOT SOL	137974	182407	220971	243221	268106	295952	327104
CHLORIDE	20781	27473	33281	36632	40380	44574	49266
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	17459	23081	27960	30776	33925	37448	41390

TRADING AREA NUMBER 14 VICTORIA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	186	296	415	508	620	757	924
SUS SOL	259	412	577	705	861	1052	1283
TOT SOL	7176	11431	16012	19573	23914	29196	35616
CHLORIDE	2565	4085	5722	6994	8545	10433	12727
NITRATES	227	362	508	620	758	926	1129
PHOSPHATES	248	395	554	677	827	1010	1232
INDUSTRIAL							
BOD	5691	9290	12969	15199	17837	20960	24660
SUS SOL	18373	29992	41872	49071	57588	67670	79618
TOT SOL	487620	795989	1111271	1302345	1528365	1795955	2113038
CHLORIDE	139343	227463	317559	372161	436749	513215	603826
COD	56908	92896	129691	151991	178369	209598	246603
SULFATES	3089	5043	7040	8251	9683	11378	13387

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 15 CORPUS CHRISTI

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	930	1238	1619	2080	2678	3453	4459
SUS SOL	2681	3569	4666	5994	7718	9953	12852
TOT SOL	42948	57176	74749	96033	123642	159458	205897
CHLORIDE	13732	18282	23901	30706	39534	50986	65835
NITRATES	1258	1675	2190	2814	3623	4672	6033
PHOSPHATES	1313	1748	2285	2936	3780	4875	6295
INDUSTRIAL							
BOD	15758	24168	32586	37207	40946	46633	53062
SUS SOL	20024	30710	41407	47279	52030	59257	67426
TOT SOL	154517	236982	319527	364843	401502	457274	520315
CHLORIDE	67749	103906	140098	159967	176040	200494	228134
COD	16360	25091	33831	38629	42510	48415	55090
SULFATES	68150	104522	140928	160915	177083	201682	229486

TRADING AREA NUMBER 16 LOWER VALLEY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2257	2799	3363	3909	4546	5290	6159
SUS SOL	5077	6298	7566	8795	10229	11902	13857
TOT SOL	71856	89135	107084	124477	144765	168450	196120
CHLORIDE	18193	22568	27113	31516	36653	42650	49655
NITRATES	1622	2012	2417	2810	3268	3802	4427
PHOSPHATES	1692	2099	2522	2932	3410	3967	4619
INDUSTRIAL							
BOD	58	61	64	67	70	74	78
SUS SOL	1008	1060	1125	1170	1233	1296	1360
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	86429	90835	96390	100323	105674	111091	116531
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 17 LAREDO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1217	1534	1858	2163	2520	2934	3418
SUS SOL	647	816	988	1151	1340	1561	1818
TOT SOL	10159	12807	15515	18067	21041	24506	28541
CHLORIDE	2291	2888	3498	4074	4744	5525	6435
NITRATES	349	440	534	621	724	843	982
PHOSPHATES	311	392	474	552	643	749	873
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	588	831	1053	1196	1356	1539	1746
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	1470	2077	2633	2990	3390	3847	4366

TRADING AREA NUMBER 18 DEL RIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	11	14	16	18	21	24	28
SUS SOL	28	34	40	46	53	61	70
TOT SOL	2771	3338	3935	4518	5206	6013	6964
CHLORIDE	499	601	709	814	938	1083	1255
NITRATES	168	203	239	274	316	365	423
PHOSPHATES	135	162	191	220	253	292	338
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	5	4	4	4	5	5	5
TOT SOL	415	363	350	370	393	420	445
CHLORIDE	116	101	98	103	110	117	124
COD	21	18	18	19	20	21	22
SULFATES	96	84	81	86	91	98	103

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 19 BROWNWOOD

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	262	353	437	499	570	652	747
SUS SOL	277	373	463	528	604	691	791
TOT SOL	3252	4378	5426	6195	7078	8096	9269
CHLORIDE	848	1141	1414	1615	1845	2110	2416
NITRATES	177	239	296	338	386	441	505
PHOSPHATES	185	249	309	352	403	460	527
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	8752	10325	11802	12999	14318	15771	17374
TOT SOL	43515	51334	58680	64632	71190	78416	86382
CHLORIDE	4509	5320	6081	6697	7377	8126	8951
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	3846	4537	5186	5712	6291	6930	7634

TRADING AREA NUMBER 20 SAN ANGELO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	857	1132	1422	1697	2029	2427	2906
SUS SOL	720	951	1194	1426	1704	2039	2441
TOT SOL	10954	14463	18169	21693	25928	31018	37136
CHLORIDE	3086	4074	5118	6111	7304	8737	10461
NITRATES	394	521	654	781	933	1116	1337
PHOSPHATES	411	543	682	815	974	1165	1395
INDUSTRIAL							
BOD	40	46	51	54	57	60	63
SUS SOL	108	124	138	145	153	161	170
TOT SOL	2323	2655	2957	3114	3281	3457	3644
CHLORIDE	1084	1241	1380	1453	1531	1613	1701
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 21 ABILENE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	766	995	1210	1373	1559	1769	2007
SUS SOL	1085	1410	1715	1946	2208	2506	2844
TOT SOL	16275	21144	25719	29184	33120	37587	42654
CHLORIDE	3702	4809	5850	6638	7533	8549	9702
NITRATES	734	954	1160	1316	1494	1695	1924
PHOSPHATES	766	995	1210	1373	1559	1769	2007
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	321	389	464	475	486	498	511
TOT SOL	58040	70280	83839	85802	87880	90075	92402
CHLORIDE	1440	1744	2081	2129	2181	2236	2293
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	27525	33329	39759	40690	41676	42717	43820

TRADING AREA NUMBER 22 BIG SPRING

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	685	1023	1341	1513	1706	1924	2168
SUS SOL	418	624	818	923	1041	1174	1323
TOT SOL	5999	8963	11748	13257	14952	16856	18993
CHLORIDE	1230	1838	2409	2718	3066	3456	3894
NITRATES	255	381	500	564	636	717	808
PHOSPHATES	278	416	545	615	694	783	882
INDUSTRIAL							
BOD	310	370	425	467	513	564	621
SUS SOL	2242	2678	3069	3372	3708	4079	4489
TOT SOL	38724	46250	53010	58251	64043	70450	77538
CHLORIDE	3420	4085	4682	5145	5657	6223	6849
COD	665	794	910	1000	1099	1209	1331
SULFATES	3057	3651	4185	4599	5056	5562	6121

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 23 MIDLAND ODESSA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	873	1143	1396	1584	1798	2040	2316
SUS SOL	2023	2651	3237	3673	4168	4730	5369
TOT SOL	37960	49736	60744	68918	78206	88759	100755
CHLORIDE	7775	10186	12441	14115	16017	18179	20635
NITRATES	1230	1611	1968	2232	2533	2875	3264
PHOSPHATES	952	1247	1523	1728	1961	2226	2527
INDUSTRIAL							
BOD	435	615	805	903	1016	1149	1304
SUS SOL	130415	184379	241155	270441	304527	344267	390680
TOT SOL	139739	197560	258396	289775	326299	368880	418611
CHLORIDE	49264	69648	91095	102157	115033	130045	147577
COD	1255	1775	2321	2603	2932	3314	3761
SULFATES	10763	15217	19903	22320	25133	28413	32243

TRADING AREA NUMBER 24 EL PASO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2369	3076	3891	4796	5912	7288	8987
SUS SOL	1992	2587	3272	4033	4971	6129	7557
TOT SOL	36722	47681	60318	74337	91631	112969	139303
CHLORIDE	8615	11186	14151	17440	21497	26503	32681
NITRATES	1238	1608	2034	2507	3090	3810	4698
PHOSPHATES	1292	1678	2123	2616	3225	3975	4902
INDUSTRIAL							
BOD	406	515	612	681	759	846	944
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	108461	137674	163635	182115	202858	226135	252271
CHLORIDE	6337	8044	9561	10641	11853	13213	14740
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	14129	17935	21317	23725	26427	29459	32864

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 25 LUBBOCK

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	5643	7790	9807	11227	12861	14741	16902
SUS SOL	6118	8446	10633	12173	13945	15982	18325
TOT SOL	50136	69204	87130	99746	114264	130963	150157
CHLORIDE	9029	12463	15692	17964	20578	23586	27042
NITRATES	1782	2460	3097	3545	4062	4655	5337
PHOSPHATES	1426	1968	2478	2836	3249	3724	4270
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	722	826	920	970	1027	1096	1179
TOT SOL	15465	17691	19719	20777	22014	23485	25258
CHLORIDE	3093	3538	3944	4155	4403	4697	5052
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	3093	3538	3944	4155	4403	4697	5052

TRADING AREA NUMBER 26 AMARILLO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4153	6504	8679	9715	10877	12180	13641
SUS SOL	3678	5761	7687	8605	9634	10788	12082
TOT SOL	35775	56026	74765	83688	93697	104921	117511
CHLORIDE	5933	9291	12399	13879	15538	17400	19488
NITRATES	1602	2509	3348	3747	4195	4698	5262
PHOSPHATES	1424	2230	2976	3331	3729	4176	4677
INDUSTRIAL							
BOD	56330	79917	99291	103899	108768	113917	119368
SUS SOL	2337	3316	4120	4311	4513	4727	4953
TOT SOL	346980	492270	611608	639992	669983	701700	735279
CHLORIDE	60654	86052	106913	111875	117117	122662	128531
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	430073	610156	758073	793254	830427	869740	911360

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 27 WICHITA FALLS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1491	1954	2410	2786	3224	3732	4322
SUS SOL	2207	2891	3566	4124	4771	5523	6397
TOT SOL	14884	19497	24049	27807	32173	37243	43136
CHLORIDE	3311	4337	5350	6186	7157	8285	9595
NITRATES	895	1172	1446	1672	1934	2239	2593
PHOSPHATES	716	938	1157	1337	1547	1791	2075
INDUSTRIAL							
BOD	2816	3290	3670	3817	3969	4128	4293
SUS SOL	3240	3786	4224	4393	4568	4750	4940
TOT SOL	22214	25954	28956	30112	31314	32565	33865
CHLORIDE	10623	12411	13847	14400	14974	15572	16194
COD	1117	1306	1457	1515	1575	1638	1703
SULFATES	2287	2672	2981	3100	3224	3353	3486

TRADING AREA NUMBER 28 GAINESVILLE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	163	238	315	380	459	553	667
SUS SOL	163	238	315	380	459	553	667
TOT SOL	2514	3669	4868	5871	7080	8536	10291
CHLORIDE	397	580	769	927	1119	1349	1626
NITRATES	91	133	177	213	257	310	374
PHOSPHATES	95	139	185	223	268	324	390
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 29 SHERMAN DENISON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	562	755	975	1211	1503	1866	2316
SUS SOL	710	954	1232	1529	1898	2357	2926
TOT SOL	12903	17322	22383	27781	34485	42812	53155
CHLORIDE	3048	4092	5288	6563	8147	10114	12557
NITRATES	340	457	590	733	910	1129	1402
PHOSPHATES	355	477	616	765	949	1178	1463
INDUSTRIAL							
BOD	338	450	557	617	688	772	872
SUS SOL	343	456	565	626	698	783	884
TOT SOL	13718	18227	22583	25030	27910	31313	35346
CHLORIDE	-0	-0	-0	-0	-0	-0	-0
COD	27437	36454	45166	50060	55820	62625	70692
SULFATES	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 30 PARIS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	275	436	599	705	829	976	1148
SUS SOL	99	158	217	255	300	353	415
TOT SOL	2753	4371	6007	7064	8310	9777	11506
CHLORIDE	614	974	1339	1575	1852	2180	2565
NITRATES	129	204	281	330	388	457	537
PHOSPHATES	140	223	306	360	423	498	586
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	15037	39609	71174	82358	95341	110421	127937
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	50	132	237	275	318	368	426

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 31 SULFUR SPRINGS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	48	79	116	155	207	275	366
SUS SOL	65	107	159	212	282	375	499
TOT SOL	626	1029	1524	2031	2706	3602	4792
CHLORIDE	176	290	429	571	761	1013	1348
NITRATES	48	79	116	155	207	275	366
PHOSPHATES	52	86	127	169	225	300	399
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	63	72	78	78	78	78	78
CHLORIDE	27	31	34	34	34	34	34
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 32 NORTHEAST TEXAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1133	1476	1866	2253	2726	3306	4017
SUS SOL	748	975	1232	1488	1800	2183	2653
TOT SOL	9966	12982	16408	19808	23967	29064	35318
CHLORIDE	2481	3232	4084	4931	5966	7235	8792
NITRATES	492	641	810	978	1183	1434	1743
PHOSPHATES	513	669	845	1020	1234	1497	1819
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0
TOT SOL	-0	-0	-0	-0	-0	-0	-0
CHLORIDE	300072	365943	403813	402242	400793	399477	398301
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX D, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

TRADING AREA NUMBER 33 STATE TOTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	64545	91436	119291	142685	170998	205321	246994
SUS SOL	82995	116961	152716	184061	222302	269037	326247
TOT SOL	1302559	1835740	2398566	2895632	3502569	4244857	5154037
CHLORIDE	293895	413149	540439	655781	797393	971553	1186086
NITRATES	48899	69085	90294	108803	131390	159007	192836
PHOSPHATES	49567	70111	91819	110970	134396	163106	198352
INDUSTRIAL							
BOD	355095	507945	655324	740294	835945	956324	1084331
SUS SOL	782077	1112446	1447019	1654090	1891923	2184812	2508287
TOT SOL	10622390	16247035	21947556	25425401	29440923	34509668	39965368
CHLORIDE	8762425	13832490	19070397	22246867	25951170	30638925	35734840
COD	1173870	1902797	2680339	3156857	3717468	4421683	5207762
SULFATES	2125210	3027041	3897768	4390128	4943752	5641267	6372659

APPENDIX E

ADDITIONAL POLLUTANT REMOVAL REQUIRED (IN THOUSANDS OF POUNDS PER YEAR) TO IMPROVE BOD AND SUSPENDED SOLIDS OF EFFLUENTS TO 20 mg/l

APPENDIX E

ADDITIONAL POLLUTANT REMOVAL REQUIRED (IN THOUSANDS OF POUNDS PER YEAR) TO IMPROVE BOD AND SUSPENDED SOLIDS OF EFFLUENTS TO 20 mg/l

APPENDIX E

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 1 FORT WORTH

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1289	1730	2225	2740	3376	4160	5125
SUS SOL	2210	2965	3814	4698	5787	7131	8786
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	25236	25997	27293	29156	31183	33392	35801

TRADING AREA NUMBER 2 DALLAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4375	6606	8774	10247	11939	13872	16070
SUS SOL	7291	11010	14623	17078	19898	23120	26783
INDUSTRIAL							
BOD	64877	71175	76230	79696	83323	87120	91097
SUS SOL	11332	12432	13315	13921	14554	15217	15912

TRADING AREA NUMBER 3 TYLER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	299	457	640	816	1044	1337	1714
SUS SOL	509	777	1087	1388	1774	2272	2913
INDUSTRIAL							
BOD	2179	2785	3262	3448	3664	3914	4203
SUS SOL	7814	9987	11696	12366	13140	14036	15072

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 4 LONGVIEW MARSHAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	215	289	386	505	663	871	1146
INDUSTRIAL							
BOD	2429	3537	4733	5727	6942	8430	10254
SUS SOL	11874	17288	23134	27992	33931	41203	50122

TRADING AREA NUMBER 5 WACO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1375	2050	2774	3391	4158	5114	6307
SUS SOL	1237	1845	2496	3052	3743	4603	5676
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	110270	128913	150896	176904	207975	245121	289571

TRADING AREA NUMBER 6 PALESTINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	366	505	661	817	1012	1255	1561
SUS SOL	321	443	580	717	888	1102	1369
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	2766	3132	3432	3646	3872	4111	4367

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 7 LUFKIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	165	244	328	398	483	586	710
SUS SOL	294	435	586	710	861	1044	1266
INDUSTRIAL							
BOD	14996	18158	21617	25308	29638	34717	40676
SUS SOL	682	825	983	1150	1347	1578	1849

TRADING AREA NUMBER 8 MIDDLE SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	33	46	60	74	91	112	138
SUS SOL	123	170	223	274	337	415	511
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	6	7	8	8	8	8	8

TRADING AREA NUMBER 9 AUSTIN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	590	846	1129	1388	1704	2087	2550
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	23744	39444	55429	59194	63224	67538	72157

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 10 BRYAN

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	43	61	82	102	128	160	200
SUS SOL	455	655	876	1090	1360	1703	2138
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	27	35	41	44	46	49	53

TRADING AREA NUMBER 11 HOUSTON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2677	3784	5066	6422	8139	10314	13066
SUS SOL	9814	13875	18576	23547	29844	37817	47910
INDUSTRIAL							
BOD	143239	219584	292240	337150	387929	453752	519416
SUS SOL	243847	373816	497504	573958	660403	772459	884244

TRADING AREA NUMBER 12 LOWER SABINE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	141	207	289	382	504	665	878
INDUSTRIAL							
BOD	12021	21894	33951	41296	50319	61373	74871
SUS SOL	35060	63857	99025	120446	146764	179005	218373

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 13 SAN ANTONIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	254	357	452	513	582	659	746
SUS SOL	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	2443	3230	3912	4306	4747	5240	5792
SUS SOL	89214	117944	142880	157267	173358	191363	211506

TRADING AREA NUMBER 14 VICTORIA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	52	82	115	141	172	210	257
INDUSTRIAL							
BOD	2439	3981	5558	6514	7644	8983	10569
SUS SOL	15121	24684	34461	40386	47395	55693	65526

TRADING AREA NUMBER 15 CORPUS CHRISTI

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	1587	2112	2761	3548	4568	5891	7606
INDUSTRIAL							
BOD	14754	22628	30510	34837	38338	43663	49683
SUS SOL	19020	29171	39331	44909	49422	56287	64047

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 16 LOWER VALLEY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	846	1050	1261	1466	1705	1984	2310
SUS SOL	3667	4549	5465	6352	7387	8596	10008
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	432	454	482	502	528	555	583

TRADING AREA NUMBER 17 LAREDO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	958	1207	1463	1703	1983	2310	2690
SUS SOL	388	489	593	690	804	937	1091
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 18 DEL RIO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	2	2	2	2	2	2	2

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 19 BROWNWOOD

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	108	145	180	206	235	269	307
SUS SOL	123	166	206	235	268	307	351
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	8643	10196	11655	12837	14140	15575	17158

TRADING AREA NUMBER 20 SAN ANGELO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	514	679	853	1018	1217	1456	1743
SUS SOL	377	498	626	747	893	1068	1279
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	46	53	59	62	66	69	73

TRADING AREA NUMBER 21 ABILENE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	128	166	202	229	260	295	335
SUS SOL	447	580	706	801	909	1032	1171
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	138	167	199	203	208	214	219

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 22 BIG SPRING

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	453	676	886	1000	1128	1272	1433
SUS SOL	186	277	364	410	463	522	588
INDUSTRIAL							
BOD	133	159	182	200	220	242	266
SUS SOL	2065	2466	2826	3106	3415	3756	4134

TRADING AREA NUMBER 23 MIDLAND ODESSA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	79	104	127	144	163	185	211
SUS SOL	1230	1611	1968	2232	2533	2875	3264
INDUSTRIAL							
BOD	100	142	186	208	235	265	301
SUS SOL	130080	183905	240536	269746	303746	343384	389677

TRADING AREA NUMBER 24 EL PASO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1292	1678	2123	2616	3225	3975	4902
SUS SOL	915	1189	1504	1853	2284	2816	3472
INDUSTRIAL							
BOD	126	160	190	211	235	263	293
SUS SOL	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 25 LUBBOCK

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4455	6150	7743	8864	10154	11638	13343
SUS SOL	4930	6806	8569	9809	11237	12879	14767
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	309	354	394	416	440	470	505

TRADING AREA NUMBER 26 AMARILLO

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2966	4646	6199	6939	7769	8700	9744
SUS SOL	2492	3902	5208	5829	6526	7308	8185
INDUSTRIAL							
BOD	53993	76601	95171	99588	104255	109190	114415
SUS SOL	0	0	0	0	0	0	0

TRADING AREA NUMBER 27 WICHITA FALLS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	895	1172	1446	1672	1934	2239	2593
SUS SOL	1611	2110	2602	3009	3482	4030	4668
INDUSTRIAL							
BOD	2667	3116	3476	3615	3759	3910	4066
SUS SOL	3091	3612	4030	4191	4358	4532	4713

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 28 GAINESVILLE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	83	122	161	195	235	283	341
SUS SOL	83	122	161	195	235	283	341
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 29 SHERMAN DENISON

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	266	358	462	573	712	884	1097
SUS SOL	414	556	719	892	1107	1375	1707
INDUSTRIAL							
BOD	247	328	406	451	502	564	636
SUS SOL	252	334	414	459	512	574	648

TRADING AREA NUMBER 30 PARIS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	158	251	344	405	476	560	660
SUS SOL	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX E, CONTINUED

ADDITIONAL WASTE REMOVAL REQUIRED TO IMPROVE BOD AND SS OF EFFLUENTS TO 20 MG/L (1000 LB/YEAR)

TRADING AREA NUMBER 31 SULFUR SPRINGS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4	7	11	14	19	25	33
SUS SOL	22	36	53	71	94	125	166
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 32 NORTHEAST TEXAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	706	919	1162	1403	1697	2058	2501
SUS SOL	321	418	528	638	771	936	1137
INDUSTRIAL							
BOD	-0	-0	-0	-0	-0	-0	-0
SUS SOL	-0	-0	-0	-0	-0	-0	-0

TRADING AREA NUMBER 33 STATE TOTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	24786	35169	45684	53968	63863	75701	89881
SUS SOL	42044	59021	76810	92281	111098	134019	161985
INDUSTRIAL							
BOD	316642	447479	571626	642556	721751	821625	926536
SUS SOL	741073	1049076	1360026	1552871	1774038	2046191	2346319

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX F

PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS BY DRAINAGE BASINS (MGY)

APPENDIX F

PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

DRAINAGE BASIN		1960	1970	1980	1990	2000	2010	2020
CANADIAN RIVER	MUN	5512	8940	12058	13526	15165	16993	19030
CANADIAN RIVER	IND	12282	17775	21847	22805	23804	24847	25937
CANADIAN RIVER	TOT	17794	26715	33905	36331	38969	41841	44967
RED RIVER	MUN	6266	8455	10567	12234	14159	16382	18949
RED RIVER	IND	2515	3248	3794	4006	4231	4468	4718
RED RIVER	TOT	8781	11703	14361	16240	18390	20850	23667
SULPHUR RIVER	MUN	5583	7702	9960	12074	14635	17738	21496
SULPHUR RIVER	IND	6910	11266	14823	15742	16717	17752	18852
SULPHUR RIVER	TOT	12493	18968	24783	27816	31352	35491	40348
CYPRESS CREEK	MUN	1462	1799	2154	2507	2919	3397	3954
CYPRESS CREEK	IND	3425	4142	4551	4543	4535	4527	4520
CYPRESS CREEK	TOT	4887	5941	6704	7050	7454	7925	8474
SABINE RIVER	MUN	5410	7426	9879	12739	16425	21176	27301
SABINE RIVER	IND	3259	6172	9128	10543	12178	14066	16247
SABINE RIVER	TOT	8669	13598	19007	23282	28603	35242	43547
NECHES RIVER	MUN	6475	9775	13751	18028	23632	30972	40588
NECHES RIVER	IND	31511	54381	78518	94854	114589	138431	167234
NECHES RIVER	TOT	37986	64156	92269	112882	138221	169403	207822
NECHES TRINITY C	MUN	0	0	0	0	0	0	0
NECHES TRINITY C	IND	0	0	0	0	0	0	0
NECHES TRINITY C	TOT	0	0	0	0	0	0	0
TRINITY RIVER	MUN	65859	95262	124268	146167	171411	200344	233281
TRINITY RIVER	IND	19212	23074	26763	29980	33584	37621	42143
TRINITY RIVER	TOT	85071	118336	151031	176147	204995	237965	275424
TRINITY SAN JACI	MUN	0	0	0	0	0	0	0
TRINITY SAN JACI	IND	0	0	0	0	0	0	0
TRINITY SAN JACI	TOT	0	0	0	0	0	0	0
SAN JACINTO RIVE	MUN	733	1036	1387	1758	2229	2825	3580
SAN JACINTO RIVE	IND	1249	1915	2550	2953	3419	3959	4584
SAN JACINTO RIVE	TOT	1982	2950	3937	4711	5648	6784	8164
SAN JACINTO BRAZ	MUN	1424	2013	2695	3418	4333	5491	6958
SAN JACINTO BRAZ	IND	3167	4855	6468	7490	8673	10043	11630
SAN JACINTO BRAZ	TOT	4592	6869	9164	10908	13006	15534	18588

APPENDIX F, CONTINUED

PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

DRAINAGE BASIN		1960	1970	1980	1990	2000	2010	2020
BRAZOS RIVER	MUN	22544	31588	40932	49056	58779	70409	84320
BRAZOS RIVER	IND	4573	5401	6247	7077	8018	9084	10291
BRAZOS RIVER	TOT	27117	36988	47179	56134	66797	79493	94611
BRAZOS COLORADO	MUN	506	734	986	1228	1530	1905	2371
BRAZOS COLORADO	IND	377	782	1245	1517	1849	2254	2747
BRAZOS COLORADO	TOT	883	1516	2231	2746	3379	4159	5118
COLORADO RIVER	MUN	16543	23177	30010	35912	42934	51280	61185
COLORADO RIVER	IND	7539	10745	13517	15011	16669	18511	20556
COLORADO RIVER	TOT	24082	33922	43528	50923	59604	69791	81741
COLORADO LAVACA	MUN	158	233	316	391	485	602	745
COLORADO LAVACA	IND	1687	2851	4023	4741	5589	6587	7765
COLORADO LAVACA	TOT	1846	3084	4338	5133	6074	7189	8510
LAVACA RIVER	MUN	534	695	855	995	1157	1345	1563
LAVACA RIVER	IND	83	168	260	311	372	445	533
LAVACA RIVER	TOT	617	863	1115	1306	1529	1790	2096
LAVACA GUADALUPE	MUN	0	0	0	0	0	0	0
LAVACA GUADALUPE	IND	0	0	0	0	0	0	0
LAVACA GUADALUPE	TOT	0	0	0	0	0	0	0
GUADALUPE RIVER	MUN	4693	6519	8467	10284	12474	15112	18280
GUADALUPE RIVER	IND	8066	10170	11919	12984	14144	15408	16784
GUADALUPE RIVER	TOT	12758	16689	20386	23267	26618	30519	35064
SAN ANTONIO RIVE	MUN	23849	34658	44475	50398	57038	64467	72758
SAN ANTONIO RIVE	IND	2218	3125	3923	4387	4905	5486	6134
SAN ANTONIO RIVE	TOT	26068	37783	48398	54785	61944	69953	78893
SAN ANTONIO NUEC	MUN	411	528	651	772	911	1070	1248
SAN ANTONIO NUEC	IND	133	180	224	254	287	326	369
SAN ANTONIO NUEC	TOT	544	708	875	1026	1199	1396	1617
NUECES RIVER	MUN	1962	2375	2766	3098	3461	3855	4279
NUECES RIVER	IND	1305	1640	1907	2052	2208	2375	2555
NUECES RIVER	TOT	3268	4015	4673	5150	5669	6230	6834
NUECES RIO GRAND	MUN	5214	6372	7637	8971	10489	12197	14093
NUECES RIO GRAND	IND	4246	6431	8393	9439	10616	11939	13427
NUECES RIO GRAND	TOT	9460	12803	16030	18411	21105	24137	27521

APPENDIX F, CONTINUED

PROJECTED MUNICIPAL AND INDUSTRIAL RETURN FLOWS (MGY)

DRAINAGE BASIN		1960	1970	1980	1990	2000	2010	2020
RIO GRANDE	MUN	10489	13370	16553	19905	23926	28748	34528
RIO GRANDE	IND	2862	3485	4026	4412	4835	5299	5808
RIO GRANDE	TOT	13351	16855	20579	24317	28761	34047	40335
SABINE LAKE	MUN	8037	11950	16712	21968	28877	37957	49893
SABINE LAKE	IND	34944	62567	92440	112546	137063	166967	203453
SABINE LAKE	TOT	42981	74516	109152	134514	165940	204924	253346
GALVESTON BAY	MUN	48726	68877	92210	116921	148219	187850	238020
GALVESTON BAY	IND	98549	151032	201186	232955	269740	312334	361658
GALVESTON BAY	TOT	147276	219909	293396	349876	417960	500185	599678
MATAGORDA BAY	MUN	581	886	1210	1458	1757	2119	2554
MATAGORDA BAY	IND	9983	17790	25931	30904	36832	43897	52319
MATAGORDA BAY	TOT	10565	18677	27141	32362	38589	46016	54874
SAN ANTONIO BAY	MUN	20	36	52	63	76	91	109
SAN ANTONIO BAY	IND	561	1007	1476	1762	2104	2512	2999
SAN ANTONIO BAY	TOT	581	1043	1528	1825	2179	2603	3108
ARANSAS COPANO B	MUN	597	786	998	1222	1495	1825	2225
ARANSAS COPANO B	IND	334	433	512	553	597	645	696
ARANSAS COPANO B	TOT	931	1219	1510	1775	2092	2470	2922
CORPUS CHRISTI B	MUN	8081	9926	11952	14103	16576	19397	22580
CORPUS CHRISTI B	IND	4651	6977	9058	10167	11413	12813	14385
CORPUS CHRISTI B	TOT	12731	16903	21010	24271	27990	32209	36965
STATE TOTAL	MUN	251671	355117	463501	559198	675094	815548	985888
STATE TOTAL	IND	265642	411613	554729	643988	748972	872596	1018345
STATE TOTAL	TOT	517312	766730	1018230	1203186	1424066	1688144	2004233

APPENDIX G

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 lb/year)

APPENDIX G

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 1 CANADIAN RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	3218	5219	7039	7896	8853	9921	11110
SUS SOL	2299	3728	5028	5640	6324	7086	7936
TOT SOL	27352	44363	59835	67120	75253	84324	94433
CHLORIDE	4597	7456	10056	11281	12648	14172	15871
NITRATES	1241	2013	2715	3046	3415	3826	4285
PHOSPHATES	1103	1789	2414	2707	3035	3401	3809
INDUSTRIAL							
BOD	2561	3706	4555	4755	4963	5181	5408
SUS SOL	780838	1130060	1388941	1449847	1513359	1579668	1648966
TOT SOL	844448	1222119	1502090	1567957	1636643	1708354	1783297
CHLORIDE	307398	444879	546794	570771	595775	621879	649160
COD	7682	11118	13665	14265	14889	15542	16224
SULFATES	66376	96062	118068	123246	128644	134281	140172

RIVER BASIN NUMBER 2 RED RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2665	3596	4495	5204	6022	6968	8060
SUS SOL	3867	5218	6522	7550	8738	10110	11695
TOT SOL	31564	42591	53230	61627	71324	82522	95453
CHLORIDE	6794	9167	11457	13264	15351	17761	20545
NITRATES	1463	1974	2468	2857	3306	3826	4425
PHOSPHATES	1254	1692	2115	2449	2834	3279	3793
INDUSTRIAL							
BOD	839	1084	1266	1336	1411	1491	1574
SUS SOL	12354	15955	18637	19679	20784	21948	23176
TOT SOL	23219	29987	35028	36985	39062	41250	43558
CHLORIDE	1573	2032	2373	2506	2646	2795	2951
COD	1279	1652	1930	2038	2152	2273	2400
SULFATES	1091	1409	1645	1737	1835	1938	2046

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 3 SULPHUR RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	2607	3597	4652	5639	6835	8284	10039
SUS SOL	1769	2441	3157	3826	4638	5622	6813
TOT SOL	21279	29355	37961	46019	55780	67606	81929
CHLORIDE	4889	6745	8722	10573	12816	15533	18824
NITRATES	1024	1413	1827	2215	2685	3255	3944
PHOSPHATES	1117	1542	1994	2417	2929	3550	4303
INDUSTRIAL							
BOD	2305	3758	4945	5252	5577	5922	6289
SUS SOL	33944	55342	72814	77329	82118	87202	92606
TOT SOL	63796	104012	136852	145336	154338	163893	174049
CHLORIDE	4322	7047	9272	9847	10456	11104	11792
COD	3515	5731	7541	8009	8505	9031	9591
SULFATES	2997	4886	6428	6827	7250	7699	8176

RIVER BASIN NUMBER 4 CYPRESS CREEK

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	463	570	683	795	925	1077	1253
SUS SOL	512	630	755	878	1022	1190	1385
TOT SOL	6743	8297	9934	11562	13462	15667	18236
CHLORIDE	1683	2071	2479	2885	3360	3910	4551
NITRATES	268	330	395	460	536	623	725
PHOSPHATES	293	360	431	502	584	680	791
INDUSTRIAL							
BOD	1143	1382	1518	1516	1513	1510	1508
SUS SOL	16824	20347	22356	22316	22277	22238	22203
TOT SOL	31621	38241	42017	41943	41869	41795	41730
CHLORIDE	2142	2591	2847	2842	2837	2832	2827
COD	1742	2107	2315	2311	2307	2303	2300
SULFATES	1485	1796	1974	1970	1967	1963	1960

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 5 SABINE RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	587	805	1071	1381	1781	2296	2960
SUS SCL	1444	1982	2637	3400	4384	5651	7286
TOT SOL	16333	22420	29825	38460	49588	63932	82424
CHLORIDE	4467	6131	8157	10518	13561	17484	22541
NITRATES	1038	1424	1895	2444	3151	4062	5237
PHOSPHATES	1083	1486	1977	2550	3288	4239	5465
INDUSTRIAL							
BOD	408	772	1142	1319	1523	1760	2032
SUS SOL	3724	7052	10429	12046	13914	16072	18563
TOT SOL	45961	87043	128732	148687	171746	198372	229130
CHLORIDE	32535	61615	91125	105251	121573	140421	162193
COD	3995	7567	11191	12926	14930	17245	19918
SULFATES	16879	31966	47275	54604	63072	72850	84145

RIVER BASIN NUMBER 6 NECHES RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1782	2690	3785	4962	6504	8524	11171
SUS SOL	2376	3587	5046	6616	8672	11365	14894
TOT SOL	24571	37093	52181	68411	89676	117529	154019
CHLORIDE	5238	7908	11124	14584	19118	25056	32835
NITRATES	1188	1794	2523	3308	4336	5683	7447
PHOSPHATES	1296	1957	2752	3608	4730	6199	8124
INDUSTRIAL							
BOD	30748	53064	76616	92557	111814	135078	163184
SUS SCL	25492	43993	63519	76735	92700	111988	135289
TOT SOL	839126	1448145	2090905	2525926	3051462	3686365	4453378
CHLORIDE	870662	1502570	2169485	2620856	3166142	3824907	4620746
COD	156893	270762	390940	472276	570536	689245	832655
SULFATES	46779	80730	116562	140813	170110	205504	248262

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 7 NECHES TRINITY COASTAL A

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
NITRATES	0	0	0	0	0	0	0
PHOSPHATES	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
COD	0	0	0	0	0	0	0
SULFATES	0	0	0	0	0	0	0

RIVER BASIN NUMBER 8 TRINITY RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	17576	25424	33165	39009	45746	53468	62258
SUS SOL	20872	30190	39383	46323	54324	63493	73931
TOT SOL	313081	452856	590745	694849	814854	952395	1108971
CHLORIDE	65912	95338	124367	146284	171548	200504	233468
NITRATES	12084	17479	22801	26819	31450	36759	42802
PHOSPHATES	13182	19068	24873	29257	34310	40101	46694
INDUSTRIAL							
BOD	176411	211873	245747	275287	308380	345449	386971
SUS SOL	56881	68315	79237	88762	99432	111384	124773
TOT SOL	803223	964687	1118919	1253416	1404094	1572875	1761932
CHLORIDE	808030	970461	1125615	1260917	1412497	1582287	1772476
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	977391	1173867	1361541	1525203	1708552	1913931	2143983

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 9 TRINITY SAN JACINTO COAS

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
NITRATES	0	0	0	0	0	0	0
PHOSPHATES	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
COD	0	0	0	0	0	0	0
SULFATES	0	0	0	0	0	0	0

RIVER BASIN NUMBER 10 SAN JACINTO RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	134	190	254	323	409	518	657
SUS SOL	141	199	266	337	428	542	687
TOT SOL	3674	5193	6952	8812	11173	14160	17944
CHLORIDE	862	1218	1631	2067	2621	3322	4210
NITRATES	134	190	254	323	409	518	657
PHOSPHATES	147	207	278	352	446	565	717
INDUSTRIAL							
BOD	24740	37931	50509	58492	67722	78418	90798
SUS SOL	19760	30297	40343	46719	54092	62635	72523
TOT SOL	44281	67893	90406	104694	121215	140360	162518
CHLORIDE	21760	33364	44427	51448	59567	68975	79864
COD	18990	29115	38770	44897	51982	60192	69694
SULFATES	13187	20219	26924	31179	36099	41801	48400

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 11 SAN JACINTO BRAZOS COAST

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	475	672	899	1140	1445	1832	2321
SUS SOL	546	772	1034	1311	1662	2107	2669
TOT SOL	14026	19827	26545	33666	42678	54084	68533
CHLORIDE	4038	5708	7642	9692	12287	15570	19730
NITRATES	273	386	517	656	831	1053	1335
PHOSPHATES	285	403	539	684	867	1099	1393
INDUSTRIAL							
BOD	31537	48346	64408	74585	86365	100008	115811
SUS SOL	27205	41705	55561	64341	74503	86271	99904
TOT SOL	179158	274648	365896	423711	490634	568135	657912
CHLORIDE	126280	193586	257902	298653	345823	400450	463729
COD	34205	52435	69856	80894	93671	108467	125607
SULFATES	18357	28141	37490	43414	50271	58212	67411

RIVER BASIN NUMBER 12 BRAZOS RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	10341	14489	18776	22502	26962	32297	38678
SUS SOL	11093	15543	20141	24138	28923	34645	41490
TOT SOL	129732	181776	235547	282298	338250	405176	485228
CHLORIDE	25006	35038	45403	54414	65199	78099	93529
NITRATES	4700	6586	8534	10228	12255	14680	17581
PHOSPHATES	4512	6323	8193	9819	11765	14093	16877
INDUSTRIAL							
BOD	496	586	677	767	869	985	1116
SUS SOL	6255	7387	8544	9680	10967	12425	14076
TOT SOL	355263	419588	485311	549792	622895	705710	799478
CHLORIDE	284973	336571	389291	441014	499654	566083	641299
COD	29252	34549	39961	45270	51289	58108	65829
SULFATES	4729	5585	6460	7319	8292	9394	10643

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (100C LB/YEAR)

RIVER BASIN NUMBER 13 BRAZCS COLORADO COASTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	118	171	230	287	357	445	554
SUS SCL	190	275	370	461	574	715	890
TOT SCL	2684	3893	5230	6514	8115	10105	12576
CHLORIDE	663	961	1291	1608	2003	2494	3105
NITRATES	97	141	189	236	293	365	455
PHOSPHATES	101	147	197	246	306	381	475
INDUSTRIAL							
BOD	41	85	135	164	200	244	298
SUS SOL	1962	4070	6479	7895	9622	11730	14296
TOT SCL	17129	35531	56568	68927	84012	102413	124814
CHLORIDE	1223	2537	4039	4922	5999	7313	8912
COD	1207	2504	3987	4858	5922	7219	8797
SULFATES	2132	4422	7040	8578	10455	12745	15533

RIVER BASIN NUMBER 14 COLORADO RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4139	5799	7509	8985	10742	12830	15308
SUS SCL	5933	8312	10762	12879	15397	18390	21942
TOT SCL	116032	162562	210488	251885	301136	359675	429148
CHLORIDE	22075	30927	40045	47921	57291	68428	81645
NITRATES	3587	5026	6507	7787	9310	11120	13267
PHOSPHATES	3311	4639	6007	7188	8594	10264	12247
INDUSTRIAL							
BOD	817	1165	1466	1627	1807	2007	2229
SUS SCL	68157	97141	122201	135708	150697	167350	185838
TOT SOL	99406	141679	178229	197928	219790	244078	271042
CHLORIDE	19869	28318	35623	39561	43930	48785	54174
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	77399	110314	138773	154111	171133	190044	211039

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 15 COLORADO LAVACA COASTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	41	60	82	101	125	156	193
SUS SOL	29	43	58	72	89	110	137
TOT SOL	846	1248	1692	2094	2597	3223	3989
CHLORIDE	202	297	403	499	619	768	951
NITRATES	29	43	58	72	89	110	137
PHOSPHATES	32	47	63	78	97	120	149
INDUSTRIAL							
BOD	507	856	1208	1423	1678	1978	2331
SUS SOL	11720	19807	27949	32937	38828	45761	53945
TOT SOL	32191	54403	76767	90467	106649	125693	148171
CHLORIDE	10172	17191	24258	28587	33701	39718	46822
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	10102	17072	24090	28390	33468	39444	46498

RIVER BASIN NUMBER 16 LAVACA RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	196	255	314	365	425	494	574
SUS SOL	192	249	307	357	415	482	561
TOT SOL	3897	5072	6239	7261	8443	9815	11406
CHLORIDE	900	1171	1440	1676	1949	2266	2633
NITRATES	107	139	171	199	232	269	313
PHOSPHATES	107	139	171	199	232	269	313
INDUSTRIAL							
BOD	42	84	130	156	186	223	267
SUS SOL	403	815	1262	1510	1806	2160	2587
TOT SOL	2073	4195	6492	7766	9289	11112	13309
CHLORIDE	782	1582	2448	2928	3503	4190	5019
COD	-0	-0	-0	-0	-0	-0	-0
SULFATES	142	287	445	532	636	761	911

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 17 LAVACA GUADALUPE COASTAL

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
NITRATES	0	0	0	0	0	0	0
PHOSPHATES	0	0	0	0	0	0	0
INDUSTRIAL							
BOD	0	0	0	0	0	0	0
SUS SOL	0	0	0	0	0	0	0
TOT SOL	0	0	0	0	0	0	0
CHLORIDE	0	0	0	0	0	0	0
COD	0	0	0	0	0	0	0
SULFATES	0	0	0	0	0	0	0

RIVER BASIN NUMBER 18 GUADALUPE RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1057	1468	1907	2316	2809	3403	4116
SUS SOL	1566	2175	2825	3431	4161	5041	6098
TOT SOL	22505	31262	40603	49317	59819	72470	87662
CHLORIDE	5714	7938	10310	12522	15189	18401	22258
NITRATES	1057	1468	1907	2316	2809	3403	4116
PHOSPHATES	939	1305	1695	2058	2497	3025	3659
INDUSTRIAL							
BOD	3094	3902	4573	4981	5426	5911	6439
SUS SOL	62023	78202	91651	99840	108760	118480	129060
TOT SOL	199121	251061	294237	320528	349164	380368	414337
CHLORIDE	46484	58609	68688	74826	81511	88795	96725
COD	23545	29686	34792	37900	41286	44976	48992
SULFATES	2489	3138	3678	4007	4365	4755	5179

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 19 SAN ANTONIO RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	3779	5492	7048	7986	9038	10215	11529
SUS SOL	2586	3758	4822	5464	6184	6990	7888
TOT SOL	105020	152617	195847	221929	251168	283882	320391
CHLORIDE	19691	28616	36721	41612	47094	53228	60073
NITRATES	5370	7804	10015	11349	12844	14517	16384
PHOSPHATES	4774	6937	8902	10088	11417	12904	14563
INDUSTRIAL							
BOD	851	1199	1505	1683	1882	2105	2353
SUS SOL	17055	24030	30166	33734	37717	42184	47167
TOT SOL	54754	77145	96845	108299	121087	135430	151426
CHLORIDE	12782	18009	22608	25282	28267	31615	35350
COD	6474	9122	11451	12806	14318	16014	17905
SULFATES	684	964	1211	1354	1514	1693	1893

RIVER BASIN NUMBER 20 SAN ANTONIO NUECES COAST

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	86	110	136	161	190	223	260
SUS SOL	106	137	168	200	236	277	323
TOT SOL	5550	7129	8790	10424	12301	14448	16851
CHLORIDE	1693	2175	2682	3181	3753	4408	5142
NITRATES	75	97	119	142	167	196	229
PHOSPHATES	82	106	130	155	182	214	250
INDUSTRIAL							
BOD	201	272	338	383	433	492	557
SUS SOL	603	817	1016	1152	1302	1479	1674
TOT SOL	2200	2977	3705	4201	4746	5391	6103
CHLORIDE	1007	1363	1696	1923	2173	2469	2794
COD	2218	3002	3736	4237	4787	5438	6155
SULFATES	900	1217	1515	1718	1941	2205	2496

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 21 NUECES RIVER

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	311	376	438	491	548	611	678
SUS SOL	1080	1307	1523	1705	1905	2122	2355
TOT SOL	12796	15489	18040	20205	22572	25142	27907
CHLORIDE	3158	3823	4452	4987	5571	6205	6888
NITRATES	409	495	577	646	722	804	892
PHOSPHATES	393	475	554	620	693	772	856
INDUSTRIAL							
BOD	3428	4308	5010	5391	5801	6239	6712
SUS SOL	1807	2270	2640	2841	3057	3288	3537
TOT SOL	10949	13760	16000	17216	18525	19926	21437
CHLORIDE	12233	15374	17877	19236	20698	22264	23951
COD	39715	49910	58035	62448	67195	72278	77755
SULFATES	17240	21665	25193	27108	29169	31375	33753

RIVER BASIN NUMBER 22 NUECES RIO GRANDE COASTA

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	1305	1594	1911	2245	2624	3052	3526
SUS SOL	3000	3667	4395	5162	6036	7019	8110
TOT SOL	54356	66428	79616	93523	109348	127154	146920
CHLORIDE	13524	16527	19808	23268	27206	31636	36554
NITRATES	1044	1275	1529	1796	2099	2441	2821
PHOSPHATES	1044	1275	1529	1796	2099	2441	2821
INDUSTRIAL							
BOD	2656	4023	5250	5904	6640	7468	8399
SUS SOL	5312	8045	10500	11808	13281	14936	16797
TOT SOL	106235	160904	209993	236164	265612	298714	335944
CHLORIDE	77906	117996	153995	173187	194782	219057	246359
COD	12394	18772	24499	27552	30988	34850	39193
SULFATES	-0	-0	-0	-0	-0	-0	-0

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 23 RIO GRANDE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	4811	6133	7593	9130	10975	13187	15838
SUS SOL	4024	5129	6350	7636	9179	11029	13246
TOT SOL	58698	74820	92633	111391	133893	160878	193224
CHLORIDE	13734	17506	21674	26063	31328	37642	45210
NITRATES	2099	2676	3313	3984	4789	5754	6911
PHOSPHATES	2099	2676	3313	3984	4789	5754	6911
INDUSTRIAL							
BOD	454	552	638	699	766	840	920
SUS SOL	79842	97222	112315	123083	134883	147828	162028
TOT SOL	104714	127508	147302	161424	176901	193878	212501
CHLORIDE	67287	81934	94653	103728	113673	124582	136549
COD	1193	1453	1679	1840	2016	2210	2422
SULFATES	33441	40720	47041	51551	56494	61915	67863

RIVER BASIN NUMBER 24 SABINE LAKE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	737	1096	1533	2015	2649	3482	4577
SUS SOL	1408	2093	2927	3847	5058	6548	8738
TOT SOL	28085	41759	58399	76766	100910	132639	174349
CHLORIDE	8245	12259	17144	22535	29623	38937	51181
NITRATES	1475	2193	3066	4031	5298	6964	9154
PHOSPHATES	1475	2193	3066	4031	5298	6964	9154
INDUSTRIAL							
BOD	12823	22960	33922	41300	50297	61270	74659
SUS SOL	26229	46963	69385	84477	102879	125325	152712
TOT SOL	859144	1538292	2272759	2767092	3369875	4105104	5002161
CHLORIDE	1108320	1984439	2931921	3569624	4347230	5295696	6452923
COD	210997	377790	558168	679571	827608	1008173	1228482
SULFATES	63824	114276	168838	205561	250340	304959	371599

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 25 GALVESTON BAY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	9347	13212	17688	22428	28431	36033	45657
SUS SOL	16255	22977	30761	39005	49446	62667	79403
TOT SOL	264550	373957	500639	634804	804731	1019902	1292292
CHLORIDE	65833	93058	124583	157970	200256	253800	321584
NITRATES	8940	12638	16919	21453	27195	34467	43672
PHOSPHATES	8940	12638	16919	21453	27195	34467	43672
INDUSTRIAL							
BOD	154517	236806	315444	365255	422931	489715	567051
SUS SOL	251501	385440	513435	594510	688387	797089	922966
TOT SOL	6524232	9998759	13319101	15422301	17857576	20677423	23942816
CHLORIDE	5806714	8899123	11854302	13726198	15893647	18403375	21309649
COD	674779	1034137	1377549	1595075	1846948	2138595	2476323
SULFATES	996963	1527903	2035282	2356671	2728803	3159702	3658684

RIVER BASIN NUMBER 26 MATAGORDA BAY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	184	281	383	462	557	672	809
SUS SOL	233	355	484	584	703	848	1022
TOT SOL	3435	5239	7155	8621	10389	12530	15102
CHLORIDE	887	1352	1847	2225	2682	3234	3898
NITRATES	107	163	222	268	322	389	469
PHOSPHATES	107	163	222	268	322	389	469
INDUSTRIAL							
BOD	2914	5193	7569	9021	10751	12814	15272
SUS SOL	9408	16766	24438	29125	34711	41369	49306
TOT SOL	249691	444957	648577	772960	921229	1097937	1308585
CHLORIDE	71352	127152	185339	220883	263252	313749	373944
COD	29140	51929	75693	90209	107513	128135	152719
SULFATES	1582	2819	4109	4897	5836	6956	8290

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 27 SAN ANTONIO BAY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	20	36	52	63	76	91	109
SUS SOL	11	20	29	35	42	50	60
TOT SOL	138	249	360	436	526	630	755
CHLORIDE	38	68	98	119	143	172	205
NITRATES	4	7	10	12	14	17	20
PHOSPHATES	4	7	10	12	14	17	20
INDUSTRIAL							
BOD	819	1470	2154	2572	3071	3666	4377
SUS SOL	1198	2150	3151	3762	4492	5363	6403
TOT SOL	14219	25523	37410	44658	53326	63667	76010
CHLORIDE	5165	9272	13590	16223	19372	23129	27613
COD	1581	2839	4161	4967	5931	7081	8454
SULFATES	3224	5786	8481	10125	12090	14435	17233

RIVER BASIN NUMBER 28 ARANSAS COPANO BAY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	90	118	150	183	224	274	334
SUS SOL	119	157	200	245	299	365	445
TOT SOL	5128	6752	8573	10497	12842	15677	19113
CHLORIDE	1514	1993	2530	3098	3790	4627	5641
NITRATES	110	144	183	224	274	335	408
PHOSPHATES	110	144	183	224	274	335	408
INDUSTRIAL							
BOD	875	1134	1341	1448	1563	1689	1823
SUS SOL	1111	1441	1704	1840	1987	2146	2316
TOT SOL	8577	11119	13148	14200	15330	16563	17872
CHLORIDE	3761	4875	5765	6226	6722	7262	7836
COD	908	1177	1392	1504	1623	1754	1892
SULFATES	3783	4904	5799	6263	6761	7305	7883

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

APPENDIX G, CONTINUED

QUANTITIES OF WASTES DISCHARGED BY MUNICIPAL AND INDUSTRIAL TREATMENT PLANTS IF PRESENT LEVEL OF TREATMENT IS MAINTAINED (1000 LB/YEAR)

RIVER BASIN NUMBER 29 CORPUS CHRISTI BAY

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	809	993	1196	1411	1659	1941	2260
SUS SOL	3235	3974	4785	5646	6636	7765	9039
TOT SCL	41516	50994	61403	72453	85158	99651	116003
CHLORIDE	13816	16970	20434	24112	28340	33163	38605
NITRATES	1483	1821	2193	2588	3041	3559	4143
PHOSPHATES	1483	1821	2193	2588	3041	3559	4143
INDUSTRIAL							
BOD	12180	18271	23721	26625	29888	33554	37671
SUS SCL	15477	23217	30142	33832	37979	42637	47868
TOT SCL	119432	179161	232599	261077	293073	329023	369390
CHLORIDE	52366	78554	101984	114470	128499	144262	161961
COD	12645	18969	24627	27642	31030	34836	39111
SULFATES	52676	79020	102588	115149	129260	145116	162920

RIVER BASIN NUMBER 30 SUMMARY OF STATE

POLLUTANT	1960	1970	1980	1990	2000	2010	2020
MUNICIPAL							
BOD	66878	94448	122986	147480	176914	212292	254829
SUS SCL	84885	118918	154732	186749	225474	272330	329045
TOT SCL	1313589	1843242	2398464	2890942	3485988	4205214	5074858
CHLORIDE	295170	412422	536502	648959	785345	950822	1151677
NITRATES	49407	69719	90908	109454	131874	158996	191829
PHOSPHATES	49272	69538	90720	109331	131840	159083	192075
INDUSTRIAL							
BOD	467404	664780	855786	984497	1133459	1306015	1506048
SUS SCL	1537086	2228848	2808817	3065507	3354535	3680958	4050581
TOT SCL	11634164	17723338	23605884	27293657	31600141	36633828	42522900
CHLORIDE	9757098	15001041	20157916	23491908	27403929	31997991	37397617
COD	1274353	2016329	2755937	3233494	3797427	4463964	5252420
SULFATES	2415851	3379169	4298451	4912324	5618358	6430981	7366972

-0 INDICATES THAT NO DATA REGARDING CONCENTRATION OF POLLUTANT WAS AVAILABLE

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APPENDIX H

OPTIMIZATION PROGRAM

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      PROGRAM ANSWER
      DIMENSION Q(7,30,8),C(7,30,8),JP(30),SW(7,30),CS(7,30),D(7,30),CA(
     17,30),CMIN(7,30),F(10,10),TRI(20,30),TRIB(20,7),ITOP(30,10,10)
      DIMENSION CSTEP(7,30,10),NCIT(30),STEM(20,30),KOP(7,30,10)
      NCP = 0
C*    NTRIB =1+NO OF ACTUAL TRIBUTARIES. (MAIN STEM IS TRIB  1)
      READ 5,NTRIB   $IF (NTRIB.EQ.1)110,6
C**   IF THERE ARE TRIBUTARIES, THEY ARE COMPUTED FIRST
    5 FORMAT (10X,I1)
    6 DO 100 I=2,NTRIB
      IF(NCP.EQ.0)7,26
    7 READ 10, NCIT(I),JP(I),Q(I,1,1),C(I,1,1)
C*    NCIT =NO OF CITIES, JP=JUNCT PT WITH MAIN STEM
      NUM=NCIT(I) $CMIN(I,1)=C(I,1,1) $CA(I,1)=C(I,1,1)
C**   READ IN DATA FOR ALL CITIES ON TRIBUTARIES
      DO 20 N=1,NUM   $L=N+1
      READ 15, Q(I,N,2),Q(I,N,3),Q(I,N,6),Q(I,N,7),SW(I,N),CS(I,N),C(I,N
     1,3),C(I,N,6),D(I,N),CA(I,L)
C*    CS =CONC ADDED BY CITY, D= DIST ALONG STREAM
C**   SUBROUTINE ROCKY COMPUTES RETURN FLOW,C AT NEXT CONTROL POINT, ETC
      CALL ROCKY (Q(I,N,1),Q(I,N,2),Q(I,N,3),Q(I,N,6),Q(I,N,7),SW(I,N),C
     1S(I,N),CMIN(I,N),C(I,N,3),C(I,N,6),D(I,N),CA(I,L),CMIN(I,L),Q(I,L,
     21),CA(I,N))
      Q(I,N,4) = Q(I,N,1)-Q(I,N,2)
C**   COMPUTE FLOW BYPASSING CITY
   15 FORMAT (10X,6F7.0,7X,F4.0,F3.0,2F7.0)
   10 FORMAT (10X,2I2,2F10.0)
   20 CONTINUE
      NP1 =NUM +1
C**   MATRIX CSTEP STORES 10 CONCENTRATIONS FOR EACH CONTROL POINT
      DO 25 N=1,NP1
      CSTEP(I,N,1)=CMIN(I,N)
C**   CMIN IS THE LOWEST CONCENTRATION ATTAINABLE
      CSTEP(I,N,10)=CA(I,N)
C**   CA IS THE MAXIMUM ALLOWABLE CONCENTRATION
      X=(CSTEP(I,N,10)-CSTEP(I,N,1))/9.
      DO 25 J=2,9
      CSTEP(I,N,J)=CSTEP(I,N,J-1)+X
   25 CONTINUE
C**   COMPUTE OPTIMUM TREATMENT PLAN FOR 10 TRIB EFF CONCENTRATIONS
   26 NUM = NCIT(I)
      DO 100 IM=1,10
      DO 85 NN=1,NUM
      N=NUM+1-NN  $L=N+1
      DO 50 J=1,10
      A=CSTEP(I,N,J)
C**   A IS INPUT CONCENTRATION TO STAGE
      DO 50 K=1,10
      B=CSTEP(I,N+1,K)
C**   B IS EFFLUENT CONCENTRATION FROM STAGE
C**   SUBROUTINE DOG COMPUTES COST ASSOCIATED WITH INPUTS AND OUTPUTS
      CALL DOG (A,B,   DOLL,CS(I,N),Q(I,N,1), Q(I,L,1),Q(I,N,2),Q(I,N,3)
     1,Q(I,N,6),Q(I,N,7),SW(I,N),D(I,N),C(I,N,3),C(I,N,6))
      F(J,K)=DOLL
C**   MATRIX F TEMPORARILY STORES COSTS FOR ALL INPUTS AND OUTPUTS
   50 CONTINUE
```

```
      ICHECK = 2
C**   CHANGE ICHECK TO 1 IF MATRIX TO BE PRINTED AS CHECK
      IF(ICHECK.EQ.1)49,56
   49 PRINT 51,I,N
   51 FORMAT (17H TRIBUTARY NUMBER,I3,14H, PLANT NUMBER,I3)
      PRINT 52,(CSTEP(I,L,K),K=1,10)
   52 FORMAT (13H OUTPUT CONC=2X,10F10.3/5X,5HINPUT)
      DO 53 M=1,10
   53 PRINT 54,CSTEP(I,N,M),(F(M,K),K=1,10)
   54 FORMAT(5X,F5.3,5X,10F10.2)
   56 IF(N.EQ.NUM)55,60
C**   CHECK FOR LAST CITY ON TRIBUTARY
   55 KK=11-IM
      GO TO 61
   60 KK=10   $GO TO 70
   61 DO 65 IL=1,10
      X=F(IL,1) $NT=1
      DO 64 JL=2,KK
      IF (F(IL,JL).LT.X)63,64
   63 X=F(IL,JL)   $NT=JL
   64 CONTINUE
C**   FIND OPTIMUM OUTPUT CONCENTRATION FOR EACH INPUT,STORE IN MATRIX
C**   TRI ALONG WITH INDEX FOR OUTPUT CONCENTRATION
      TRI(IL,N)=X
      TRI(IL+10, N) =NT
   65 CONTINUE
      GO TO 80
C**   ADD OPTIMA FOR SUCCEEDING STAGES TO THIS STAGE
   70 DO 75 IL=1,10
      DO 75 JL=1,10
   75 F(JL,IL)=F(JL,IL)+TRI(IL,L)
      GO TO 61
   80 CONTINUE
      IF(ICHECK.EQ.1)880,85
  880 PRINT 81
   81 FORMAT (16H CUMULATIVE SUMS)
      DO 82 K=1,10
   82 PRINT 83,(F(K,KP),KP=1,10)
   83 FORMAT(15X,10F10.2)
   85 CONTINUE
      KK=11-IM
   88 FORMAT (10X,7F10.0)
C**   FIND AND STORE TRIB OPTIMA FOR EACH OF 10 TRIB EFFLUENTS
      II=1
      DO 89 JJ=1,NUM
      KCP(I,JJ,KK) =TRI(II+10,JJ)
      II= TRI(II+10,JJ)
   89 CONTINUE
   91 FORMAT (1X,5HKCP =,1X,10I3)
      TRIB(KK,I)=TRI(1,1)
      TRIB(KK+10,I)=TRI(11,1)
  100 CONTINUE
      IF(NCP.EQ.0)110,136
C**   SKIP STATEMENTS 6 -100 IF ALL CITIES ARE ON MAIN STEM
  111 FORMAT (10X,I2,2F10.0)
  110 READ 111,NSTEM,C(1,1,1),C(1,1,1) $CMIN(1,1)=C(1,1,1)$CA(1,1)=C(1,1
     1,1)
C*    NSTEM IS NO OF CITIES + NO OF TRIBUTARIES ON MAIN STEM
      DO 130 I=1,NSTEM   $N=I+1
C**   READ DATA FOR ALL CITIES ON MAIN STEM
      READ 15,Q(1,I,2),Q(1,I,3),Q(1,I,6),Q(1,I,7),SW(1,I),CS(1,I),C(1,I,
     13),C(1,I,6),D(1,I),CA(1,N)
C**   CHECK TO SEE WHETHER CITY OR TRIB AT THIS LOCATION. IF TRIB, GO TO 125
      DO 114 IC=2,NTRIB
      IF(JP(IC).EQ.I)125,114
  114 CONTINUE
  115 Q(1,I,4)=Q(1,I,1)-Q(1,I,2)
      Q(1,I,5)=(Q(1,I,2)+Q(1,I,3))*SW(1,I)
      Q(1,N,1)=Q(1,I,4)+Q(1,I,5)+(Q(1,I,6)-Q(1,I,7))*D(1,I)
      CMIN(1,N)= (Q(1,I,4)*CMIN(1,I)+ Q(1,I,6)*D(1,I)*C(1,I,6))/Q(1,N,1)
      IF(CA(1,N).LT.CMIN(1,N))116,130
C**   IF ALLOWABLE CANNOT BE MET, PRINT ALARM, END PROGRAM
  116 PRINT 117,CA(1,N),N
  117 FORMAT (17H CONCENTRATION OF,F5.2, 8H AT CITY,I3,63H ON MAIN STEM
     1CAN NOT BE MET. REDUCE ALLOWABLE AT PREVIOUS CITY)
      GO TO 300
  125 L=NCIT(IC)+1
C**   L IS NO. OF CONTROL POINT BELOW LAST CITY ON TRIB
      Q(1,N,1)=Q(1,I,1)+(Q(1,I,6)-Q(1,I,7))*D(1,I)+Q(IC,L,1)
      CMIN(1,N)= (Q(1,I,1)*CMIN(1,I)+ Q(1,I,6)*D(1,I)*C(1,I,6)+Q(IC,L,1)
     1*CMIN(IC,L))/Q(1,N,1)
      IF (CMIN(1,N).GT.CA(1,N))116,130
  130 CONTINUE
      NS1 =NSTEM + 1
      IF(ICHECK.EQ.1)1331,1332
 1331 PRINT 131
C**   PRINT STREAMFLOW AT END OF EACH REACH AS CHECK
  131 FORMAT (1X,19HMAINSTEM QUANTITIES)
      DO 132 I = 1,NS1
  132 PRINT 133,Q(1,I,1)
  133 FORMAT (1X,F10.2)
 1332 CMIN(1,NS1) =CA(1,NS1)
C**   ESTABLISH INCREMENTAL CONCENTRATIONS FOR MAIN STEM
      DO 135 I=1,NS1
      CSTEP(1,I,1)=CMIN(1,I)
      CSTEP(1,I,10)=CA(1,I)
      X=(CA(1,I)-CMIN(1,I))/9.
      DO 135 J=2,9
  135 CSTEP(1,I,J)=CSTEP(1,I,J-1)+X
  136 DO 225 II=1,NSTEM
      I=NSTEM+1-II   $N=I+1
C**   DETERMINE WHETHER CITY OR TRIB
      DO 139 IC=2,NTRIB
      IF(JP(IC).EQ.I)150,139
  139 CONTINUE
C**   IF CITY, COMPUTE COSTS ASSOCIATED WITH INPUTS AND OUTPUTS
  140 DO 145 J=1,10
      A=CSTEP(1,I,J)
      DO 145 K=1,10
      B=CSTEP(1,N,K)
      CALL DOG (A,B,DOLL,CS(1,I),Q(I,I,1),Q(1,N,1),Q(1,I,2),Q(1,I,3),Q(1
     1,I,6),Q(1,I,7),SW(1,I),D(1,I),C(1,I,3),C(1,I,6))
  145 F(J,K)=DOLL    $GO TO 175
  150 L=NCIT(IC)+1
 C**    L IS LAST CONTROL POINT ON TRIB IC
 C**    FIND MIN TRIB COST TO MEET OUTPUT
        DO 170 J=1,10
        A=CSTEP(1,I,J)
        DO 170 K=1,10
        B=CSTEP(1,N,K)
        P=B* C(1,N,1)
        U=A* C(1,I,1)+C(1,I,6)*C(1,I,6)*D(1,I)
        P=P-U
        IF (P.LT.-0.1)151,155
  151 DOLL =1000000.
        GO TO 170
  155 DOLL =1000000.
        DO 160 M =1,10
        TC=CSTEP(IC,L,M)*C(IC,L,1)
        IF(TC.GT.P+.1)160,156
  156 DOLL=TRIB(M,IC)
        ITOP(I,J,K)=M
  160 CONTINUE
  170 F(J,K)=DOLL
  175 CONTINUE
 C**    MUD IS A CONTROL INDEX USED TO ALLOW PRINTING STAGE RETURNS AND
 C**    TOTAL RETURNS AT STAGE WITH SAME PRINT STATEMENT
        MUD=0 $GO TO 191
  176 IF(I.EQ.NSTEM)180,195
 C**    IF I = NSTEM, CITY IS LAST CITY ON MAIN STEM
  231 FORMAT (1X,10F10.0)
  180 DO 190 M=1,10
        X=F(M,1) $MM=1
        DO 185 J=2,10
 C**    FIND OPTIMUM FOR EACH CONCENTRATION
        IF(F(M,J).LT.X)181,185
  181 X=F(M,J) $MM=J
  185 CONTINUE
 C**    MATRIX STEM STORES OPTIMA FOR MAIN STEM
        STEM(M,I)=X
        STEM(M+10,I)=MM
  190 CONTINUE
        GO TO 225
  191 PRINT 196,I
  196 FORMAT (31H RETURNS FOR MAIN STEM LOCATION,I3)
        PRINT   52, (CSTEP(1,N,J),J=1,10)
        DO 197 J=1,10
  197 PRINT 54, CSTEP(1,I,J),(F(J,K),K=1,10)
        IF(MUD.EQ.0)176,180
  195 DO 200 M=1,10
        DO 200 J=1,10
  200 F(J,M)=F(J,M)+STEM(M,N)
        MUD=1  $GO TO 191
  225 CONTINUE
        Y = STEM(1,1)
 C**    FOR THE ASSUMED CONDITIONS, STEM,1,1. WILL ALWAYS BE OPTIMUM
  281 PRINT 282,Y
  282 FORMAT (1H1,10X,34HTOTAL COST OF OPTIMUM SYSTEM IS  $,F9.2,35H PER
     1DAY, DISTRIBUTED AS FOLLOWS    //11X,45HMAIN STEM LOCATION, INCLUD
     2ING TRIBUTARY COSTS/)
      PRINT 283
C**   PRINT REMOVALS AND COSTS FOR OPTIMUM SYSTEM ON MAIN STEM
  283 FORMAT (10X,73HCITY OR STAGE  INF CONC  QUANTITY  EFF CONC  QUANTI
     1TY   LBS REM      COST/)
      K = 1
      L = STEM(11,1)
      A = CSTEP(1,1,1)
      DO 290 I = 1,NSTEM
      B = CSTEP(1,I+1,L)
      DO 284 J=2,NTRIB
      IF(JP(J).EQ.I)285,284
  284 CONTINUE
      P = B*Q(1,I+1,1)
C**   P IS THE PERMISSIBLE QUANTITY OF POLLUTANT AT END OF STAGE
      U=A*Q(1,I,4) +Q(1,I,6)*D(1,I)*C(1,I,6)
C**   U IS THE POLLUTANT QUANTITY THAT CANNOT BE REMOVED
      PC = P-U
      CT=((A+CS(1,I))*Q(1,I,2)+(C(1,I,3)+CS(1,I))*Q(1,I,3))*SW(1,I)
      R = (CT-PC)*8.34
      GALI = Q(1,I,2) +Q(1,I,3)
C**   GALI IS THE INFLUENT QUANTITY, GALO IS THE EFFLUENT QUANTITY
      GALO = GALI*SW(1,I)
      GO TO 286
  285 GALI = 0.
      JJ = NCIT(J)
      GALO = Q(J,JJ+1,1)
      R = -.000001
  286 COST = STEM(K,I) -STEM(L,I+1)
      PRINT 287,I,A,GALI,B,GALO,R,COST
  287 FORMAT (20X,I3,6F10.2)
      A=B
      K=L
      L = STEM(L+10,I+1)
  290 CONTINUE
C**   NOP CONTROLS THE NUMBER OF SUCCESSIVE APPROXIMATIONS MADE
      NOP = NOP + 1
      L = STEM(11,1) $ M = 1
      IF(NOP.EQ.5)300,232
C**   REDUCE THE RANGE OF CONCENTRATIONS CONSIDERED AT THE MAIN STEM
C**   LOCATIONS TO 0.2 TIMES THE PREVIOUS VALUES
  232 DO 270 I = 1,NSTEM
      IF(L.EQ.10)236,238
  236 CSTEP(1,I+1,1)=CSTEP(1,I+1,9)
      GO TO 244
  238 IF(L.EQ.1)240,242
  240 CSTEP(1,I+1,10) = CSTEP(1,I+1,2)
      GO TO 244
  242 CSTEP(1,I+1,1) = CSTEP(1,I+1,L-1)
      CSTEP(1,I+1,10) = CSTEP(1,I+1,L+1)
  244 CONTINUE
      DO 235 II = 2,NTRIB
      IF(JP(II).EQ.I)250,235
  235 CONTINUE
      GO TO 261
  250 PRINT 301, II
  301 FORMAT (1H0,10X,43HCOST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBERI3/)
      ITT=ITOP(I,M,L)
C**   PICK OUT OPTIMUM CONCENTRATION FOR TRIBUTARY
      ICT = NCIT(II)
      DO 260 LL = 1,ICT
      LB = ICT +1 - LL
      IT = KOP(II,LB,ITT)
      B=CSTEP(II,LB+1,IT)
C**   REDUCE RANGES OF CONCENTRATIONS CONSIDERED AT TRIBUTARY STAGES
      IF (LB.EQ.1) 271,272
  271 A=CSTEP(II,1,1)
      GO TO 273
  272 IS=KOP(II,LB-1,ITT)
      A=CSTEP(II,LB,IS)
  273 CONTINUE
      IF(IT.EQ.10)251,252
  251 CSTEP(II,LB+1,1) =CSTEP(II,LB+1,9)
      GO TO 255
  252 IF(IT.EQ.1)253,254
  253 CSTEP(II,LB+1,10) = CSTEP(II,LB+1,2)
      GO TO 255
  254 CSTEP(II,LB+1,10)=CSTEP(II,LB+1,IT+1)
      CSTEP(II,LB+1,1) = CSTEP(II,LB+1,IT-1)
  255 P=B*Q(II,LB+1,1)
      U=A*Q(II,LB,4)+Q(II,LB,6)*D(II,LB)*C(II,LB,6)
      PC=P-U
      CT=((A+CS(II,LB))*Q(II,LB,2)+(C(II,LB,3)+CS(II,LB))*Q(II,LB,3))*SW
     1(II,LB)
      CON=CT/((Q(II,LB,2)+Q(II,LB,3))*SW(II,LB))
      R=(CT-PC)*8.34
      GALI= Q(II,LB,2)+Q(II,LB,3)
      GALO= GALI*SW(II,LB)
      IF(R.LT.1)257,258
  257 COST =0.  $GO TO 266
  258 IF(R.LT.100)262,263
  262 CALL SMALL(R,COST,CON)
      GO TO 266
  263 IF (R.LT.16000.)264,265
  264 CALL MED (R,COST,CON)
      GO TO 266
  265 CALL LARGE(R,COST,CON)
  266 PRINT 287,LB,A,GALI,B,GALO,R,COST
C**   PRINT OPTIMUM RESULTS FOR TRIBUTARIES
  260 CONTINUE
  261 M=L
      L = STEM(L+10,I+1)
  270 CONTINUE
      DO 280 I = 1,7
      DO 280 J = 1,30
      X = (CSTEP(I,J,10)-CSTEP(I,J,1))/9.
      DO 280 K = 2,9
  280 CSTEP(I,J,K) = CSTEP(I,J,K-1)+ X
      PRINT 302
  302 FORMAT (1H1)
      IF (NTRIB.EQ.1)136,6
      SUBROUTINE ROCKY (Q1,Q2,Q3,Q6,Q7,S,CS,CM1,C3,C6,D,CA,CM2,Q8,CA1)
C**   THIS SUBROUTINE IS USED TO COMPUTE STREAMFLOWS, CONCENTRATIONS,
C**   ETC. FROM ORIGINAL DATA
      Q4= Q1-Q2
      Q5=(Q2+Q3)*S
      Q8=Q4+Q5+(Q6-Q7)*D
      CM2=(CM1*Q4+Q6*D*C6)/Q8
      PA=Q8*CA
      U=Q4*CA1+Q6*C6*D
      IF(U.GT.PA)5,10
    5 U=U-PA
      CA1=CA1-U/Q4
   10 END

      SUBROUTINE COG (A,B, DOLL,SC,Q1,CN,Q2,Q3,Q6,Q7,W,D1,C3,C6)
C**   THIS SUBROUTINE COMPUTES COSTS OF REMOVALS
      U=A*(Q1-Q2)+Q6*C6*D1
      P=B*CN    $Q5=(Q2+Q3)*W
      IF(U.GT.P+.1)5,10
    5 DOLL=10000000.
      RETURN
   10 P=P-U
      R = (((A+SC)*Q2 +(C3+SC)*Q3)*W - P)*8.34
C**   R IS THE QUANTITY OF POLLUTANT (POUNDS) TO BE REMOVED
      CON = (R/8.34 + P)/Q5
      IF(R.LT.1.)15,20
   15 DOLL =0.
      RETURN
   20 IF(R.LT.100.)25,30
   25 CALL SMALL (R,DOLL,CON)
      RETURN
   30 IF(R.LT.16000.)35,40
   35 CALL MED (R,DOLL,CON)
      RETURN
   40 CALL LARGE (R,DOLL,CON)
      END

      SUBROUTINE SMALL (R,DOLL,CON)
C**   THIS SUBROUTINE COMPUTES COST IF R IS LESS THAN 100 POUNDS
      DOLL = (30.0 + 0.36*R)*SQRTF(20.0/CON)
      END

      SUBROUTINE MED  (R,DOLL,CON)
C**   THIS SUBROUTINE COMPUTES COST IF R IS FROM 100 TO 16000 POUNDS
      DOLL = R*(.66-.074*(LOGF(R)-LOGF(100.)))*SQRTF(20./CON)
      END

      SUBROUTINE LARGE (R,DOLL,CON)
C**   THIS SUBROUTINE COMPUTES COST IF R IS GREATER THAN 16000 POUNDS
      DOLL=R*.28*SQRTF(20./CON)
      END
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TOTAL COST OF OPTIMUM SYSTEM IS  $ 34651.26 PERDAY, DISTRIBUTED AS FOLLOWS

MAIN STEM LOCATION, INCLUDING TRIBUTARY COSTS-FIRST APPROXIMATION

CITY OR STAGE  INF CONC   QUANTITY   EFF CONC   QUANTITY    LBS REM       COST

          1        .10       1.90        .50       1.22     -18.31          0
          2        .50          0        .60       9.32       -.00     524.77
          3        .60     242.50        .13     155.20   28703.54    7628.39
          4        .13       5.70        .13       3.65     668.28     330.22
          5        .13       1.70        .24       1.09      19.25      35.13
          6        .24      12.80        .24       8.19    1490.89     652.49
          7        .24      32.80        .24      20.99    3824.48    1420.16
          8        .24      13.70       1.00       8.77      30.97      39.15
          9       1.00      21.40       1.00      13.70    2403.68     971.16
         10       1.00          0       1.00      16.25       -.00     816.07
         11       1.00          0       1.00      83.71       -.00    2409.09
         12       1.00     470.00        .78     300.80   54238.35   14425.33
         13        .78       4.50        .69       2.88     -77.20          0
         14        .69       4.10       1.00       2.62    -127.54          0
         15       1.00          0       1.00      66.60       -.00    4518.81
         16       1.00       2.10       1.00       1.13     191.67     110.50
         17       1.00          0       1.00      26.31       -.00     769.99

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  2

          2       1.00       2.70       1.00       1.73     307.30     165.97
          1        .10       6.80       1.00       4.35     736.27     358.80

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  3

          2        .06       6.40       1.00       4.10     626.11     312.26
          1        .10       9.30        .06       5.95    1097.04     503.81

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  4

          4        .07       5.10       1.00       3.26     -48.55          0
          3        .08      22.60        .07      14.46    2665.92    1057.67
          2        .10      21.60        .08      13.82    2547.96    1018.99
          1        .10       8.70        .10       3.65     673.48     332.43

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  5

          5       1.00      12.60       1.00       6.80    1229.18     543.70
          4        .24      22.60       1.00      12.20    1785.30     758.69
          3        .35      41.40        .24      22.36    4104.11    1503.61
          2        .79      33.00        .35      17.82    3279.44    1253.26
          1        .10      10.70        .79       5.78     984.29     459.54

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  6

          2       1.00      11.90       1.00       6.43    1101.58     495.59
          1        .10       7.00       1.00       3.78     538.78     274.40
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TOTAL COST OF OPTIMUM SYSTEM IS  $ 34506.26 PERDAY, DISTRIBUTED AS FOLLOWS

MAIN STEM LOCATION, INCLUDING TRIBUTARY COSTS-SECOND APPROXIMATION

CITY OR STAGE  INF CONC  QUANTITY  EFF CONC  QUANTITY   LBS REM      COST

        1         .10       1.90       .49      1.22    -11.57         0
        2         .49          0       .54      9.32      -.00    524.77
        3         .54     242.50       .12    155.20  26692.62   7627.40
        4         .12       5.70       .16      3.65    589.70    296.59
        5         .16       1.70       .30      1.09    -21.23         0
        6         .30      12.80       .30      8.19   1485.61    650.55
        7         .30      32.80       .27     20.99   3859.05   1430.56
        8         .27      13.70      1.00      8.77    101.44     63.59
        9        1.00      21.40      1.00     13.70   2403.68    971.16
       10        1.00          0      1.00     16.25      -.00    816.07
       11        1.00          0      1.00     83.71      -.00   2391.05
       12        1.00     470.00       .77    300.80  54301.90  14442.23
       13         .77       4.50       .88      2.88    -76.71         0
       14         .88       4.10       .98      2.62    -62.78         0
       15         .98          0       .96     66.60      -.00   4522.31
       16         .96       2.10      1.00      1.13    -23.96         0
       17        1.00          0      1.00     26.31      -.00    769.99

COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  2

        2        1.00       2.70      1.00      1.73    307.30    165.97
        1         .10       6.80      1.00      4.35    736.27    358.80

COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  3

        2         .06       6.40      1.00      4.10    626.11    312.26
        1         .10       9.30       .06      5.95   1097.04    503.81

COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  4

        4         .14       5.10      1.00      3.26     -3.02         0
        3         .16      22.60       .14     14.46   2661.65   1056.28
        2         .20      21.60       .16     13.82   2538.68   1015.93
        1         .10       8.70       .20      3.65    641.49    318.83

COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  5

        5        1.00      12.60       .98      6.80   1242.50    548.66
        4         .23      22.60      1.00     12.20   1779.63    756.68
        3         .39      41.40       .23     22.36   4119.30   1508.11
        2         .90      33.00       .39     17.82   3281.44   1253.89
        1         .10      10.70       .90      5.78    972.76    454.97

COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  6

        2        1.00      11.90      1.00      6.43   1101.58    495.59
        1         .10       7.00      1.00      3.78    538.78    274.40
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TOTAL COST OF OPTIMUM SYSTEM IS  $ 34451.56 PERDAY, DISTRIBUTED AS FOLLOWS
MAIN STEM LOCATION, INCLUDING TRIBUTARY COSTS-THIRD APPROXIMATION
CITY OR STAGE  INF CONC  QUANTITY  EFF CONC  QUANTITY   LBS REM      COST
         1        .10       1.90       .47       1.22      -1.10         0
         2        .47          0       .53       9.32       -.00    525.14
         3        .53     242.50       .10     155.20   28713.25   7633.48
         4        .10       5.70       .19       3.65     520.15    266.20
         5        .19       1.70       .31       1.09      -3.88         0
         6        .31      12.80       .30       8.19    1503.11    656.98
         7        .30      32.80       .27      20.99    3868.94   1433.52
         8        .27      13.70      1.00       8.77      96.22     61.49
         9       1.00      21.40      1.00      13.70    2403.68    971.16
        10       1.00          0      1.00      16.25       -.00    816.68
        11       1.00          0      1.00      83.71       -.00   2390.75
        12       1.00     470.00       .79     300.80   54163.23  14405.45
        13        .79       4.50       .89       2.88     -20.84         0
        14        .89       4.10       .98       2.62     -13.23         0
        15        .98          0       .97      66.60       -.00   4520.73
        16        .97       2.10      1.00       1.13        .00         0
        17       1.00          0      1.00      26.31       -.00    769.99
COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  2

         2       1.00       2.70       .99       1.73     308.08    166.34
         1        .10       6.80      1.00       4.35     736.27    358.80
COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  3

         2        .06       6.40       .99       4.10     627.53    312.87
         1        .10       9.30       .06       5.95    1097.04    503.81
COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  4

         4        .14       5.10      1.00       3.26        .50         0
         3        .18      22.60       .14      14.46    2666.71   1057.93
         2        .20      21.60       .18      13.82    2532.79   1013.99
         1        .10       8.70       .20       3.65     641.49    318.83
COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  5

         5       1.00      12.60       .98       6.80    1238.80    547.29
         4        .22      22.60      1.00      12.20    1773.32    754.44
         3        .37      41.40       .22      22.36    4120.67   1508.51
         2        .89      33.00       .37      17.82    3285.24   1255.07
         1        .10      10.70       .89       5.78     973.90    455.42
COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  6

         2       1.00      11.90      1.00       6.43    1101.58    495.59
         1        .10       7.00      1.00       3.78     538.78    274.40
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TOTAL COST OF OPTIMUM SYSTEM IS  $ 34448.60 PERDAY, DISTRIBUTED AS FOLLOWS

MAIN STEM LOCATION, INCLUDING TRIBUTARY COSTS-FOURTH APPROXIMATION

CITY OR STAGE  INF CONC  QUANTITY  EFF CONC  QUANTITY   LBS REM      COST

           1       .10      1.90       .47      1.22       .57         0
           2       .47         0       .53      9.32      -.00    525.09
           3       .53    242.50       .10    155.20  28715.21   7634.06
           4       .10      5.70       .19      3.65    518.27    265.37
           5       .19      1.70       .31      1.09       .07         0
           6       .31     12.80       .30      8.19   1495.07    654.03
           7       .30     32.80       .27     20.99   3868.57   1433.41
           8       .27     13.70      1.00      8.77     99.70     62.68
           9      1.00     21.40      1.00     13.70   2404.01    971.27
          10      1.00         0      1.00     16.25      -.00    816.68
          11      1.00         0      1.00     83.71      -.00   2390.33
          12      1.00    470.00       .79    300.80  54163.66  14405.56
          13       .79      4.50       .89      2.88     -5.05         0
          14       .89      4.10       .98      2.62    -14.71         0
          15       .98         0       .97     66.60      -.00   4520.14
          16       .97      2.10      1.00      1.13     -4.41         0
          17      1.00         0      1.00     26.31      -.00    769.99

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  2

           2      1.00      2.70       .99      1.73    307.99    166.30
           1       .10      6.80      1.00      4.35    736.27    358.80

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  3

           2       .06      6.40       .99      4.10    627.55    312.87
           1       .10      9.30       .06      5.95   1097.04    503.81

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  4

           4       .14      5.10      1.00      3.26       .92         0
           3       .18     22.60       .14     14.46   2665.40   1057.50
           2       .20     21.60       .18     13.82   2532.79   1013.99
           1       .10      8.70       .20      3.65    641.49    318.83

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  5

           5      1.00     12.60       .99      6.80   1237.32    546.73
           4       .22     22.60      1.00     12.20   1772.48    754.14
           3       .37     41.40       .22     22.36   4121.35   1508.71
           2       .88     33.00       .37     17.82   3285.30   1255.09
           1       .10     10.70       .88      5.78    973.99    455.46

 COST OF OPTIMUM SYSTEM FOR TRIBUTARY NUMBER  6

           2      1.00     11.90      1.00      6.43   1101.58    495.59
           1       .10      7.00      1.00      3.78    538.78    274.40
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